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TR-1043

[redacted]

VACUUM JACKETED UMBILICAL LINES
TECHNOLOGY ADVANCEMENT STUDY

VACUUM AND CO_2 JACKETED LINE REPAIR TECHNIQUES

AMETEK/Straza
790 Greenfield Drive
El Cajon, California 92021

January 1970

Final Technical Report, Task III, Sub-task 2
Contract Number NAS 10-6098

Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JOHN F. KENNEDY SPACE CENTER
Design Engineering-Mechanical Systems Division
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15. Supplementary Notes

This report is one of seven similar tasks related to vacuum jacketed components used on the service arms of the launch umbilical tower at Launch Complex 39, Kennedy Space Center, Florida.

16. Abstract

This report presents results of a study of repair techniques for vacuum and CO_2 jacketed transfer lines on the service arms of the launch umbilical tower at Launch Complex 39, Kennedy Space Center, Florida. To develop better procedures to be used by operations personnel to make on-site repairs, various types of problems were analyzed. Literature and patent searches were made, manufacturers and users were interviewed, material samples and data were studied, and state-of-the-art leak detection methods were investigated. Tests simulating field conditions were performed on prepared sample repairs, and vacuum integrity was checked. Further testing on promising materials was performed under conditions simulating actual jacketed line repairs. Adverse environmental factors, internal pressure, ruggedness, and flexural fatigue life were studied. Procedures were developed and are presented in this report. It was concluded that maintenance histories, failure analyses, and field conditions should all be used in determining repair procedures. It was recommended that further study be conducted on new materials technology advancement and on leak detection equipment. Use of transfer lines utilizing modular concepts for ease of maintenance and repair was also recommended.

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Final Report
For
Vacuum Jacketed Umbilical Lines
Technology Advancement Study
Task III, Sub-task 2
Vacuum & CO_2 Jacketed Line Repair Techniques

Contract Number NAS 10-6098
January 1970

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ABSTRACT

This Final Report documents the work performed under KSC Study NAS 10-6098, Task III, Sub-task 2, "Vacuum & CO_2 Jacketed Lines Repair Techniques." The program was divided into two parts, Phase I (Analysis) and Phase II (Testing). The principal goal of the program was to develop field repair procedures which could be used by operations personnel to make on-site repairs to vacuum and CO_2 jacketed umbilical lines such as used on the Launch Umbilical Tower at Complex 39, Cape Kennedy.

The Phase I investigative and analytical work consisted of literature surveys, vendor contacts, patent searches, equipment manufacturers and user interviews, on-site survey of Launch Complex 39 repair problems, preliminary analysis of materials data and actual material samples plus investigation of state-of-the-art leak detection methods.

The Phase II portion of the program was devoted mainly to testing. Preliminary Field Repair Procedures were generated and first applied to a large number of flat metal coupons. Tests simulating field conditions at Launch Complex 39 were performed and vacuum tight integrity checked.

After review and analysis of the preliminary testing, the most promising materials along with their procedures, were advanced to further, more complete testing on bellows assemblies simulating actual jacketed transfer line repairs. In some cases, procedures for repair materials applications were altered based on previous testing results. Tests included salt fog exposure, sand and dust, high temperature, cold shock, internal pressure, ruggedness and flexural fatigue life.

Field Repair Procedures for four methods and materials were the end result of this program. These procedures are included as the last items in the body of this report. They consist of:

a) Dow Corning #732 RTV Silicone Rubber
b) Johns-Manville "Volseal"
c) Silvalloy #45 Silver Solder
d) Heliarc "TIG" Welding

CONCLUSIONS

To supplement the usefulness of the Field Repair Procedures developed by this study program, certain conclusions which became apparent as pertinent to the total jacketed transfer line maintenance problem are presented here.

A. Maintenance history records on transfer lines can be a critical factor in time savings when decisions must be made regarding vacuum or CO_2 annulus repairs. Records which tell operations personnel the vacuum level or CO_2 charge pressure, repair history, general condition and length of service, can be an invaluable aid in borderline performance evaluations.

B. In making the decision whether to attempt a field repair (or re-repair), one of the most critical factors which must be considered is what caused the leak. A failure analysis should be made as a starting point. History records can play a critical role at this point.

C. If a line is determined to be losing gas tight integrity and the leak or leaks is/are pin-pointed (see Leak Locating Methods in Phase I Technical Report of this document) during launch preparations where a temporary leak repair, made quickly, is the obvious need, then one of the "no heat" methods of repair developed by this study can be used effectively. The Dow-Corning #732 is easier to apply and can be placed in somewhat less accessible areas than the J-M "Volseal" however, testing has indicated that once the "Volseal" has been properly applied it has greater impact resistance. The choice should, therefore, be made on the basis of field conditions taking the foregoing factors into consideration.

RECOMMENDATIONS

A. Every year new materials are being developed in the laboratories of chemical companies. It is recommended that some continuing effort be made by NASA to screen these new materials for possible applications to repair techniques.

Within the family of RTV Silicone Rubber materials this study examined and tested the currently available types, however, Dow Corning and General Electric have continuous R & D Programs developing new, improved silicones. The lines of communication to these sources should be kept open. Johns-Manville, Monsanto, Hysol, Eastman, Uniroyal and others also should be included in the group of companies presently pursuing materials technology advancement which might be of value in repairing vacuum leaks.

B. Further study is recommended in development of lightweight, miniaturized, high portable leak detection equipment of the mass spectrometer type or of equal capability. It has been found during this study, that due to the nature of the available equipment (heavy and large) leak detection is not usually attempted on swing arm service lines on the Launch Umbilical Tower.

C. It is recommended that when new transfer lines are procured, that they be specifically designed, where possible, for ease of maintenance and repair. Such designs should be modular concepts allowing for disassembly of component parts such as braid and flanges without destruction of other parts of the line assembly.

3.6 FINAL REPORT

3.7 PHASE I TECHNICAL REPORT

3.7.1 Define Line Failures

The investigation and definition of failures in the Vacuum and CO_2 Jacketed Umbilical Lines used at Launch Complex 39 was begun with a review of Unsatisfactory Condition Reports and Non-conformance Reports filed with NASA. In most cases, Unsatisfactory Condition Reports can be related to an Inspection Report filed by AMETEK/Straza when lines were returned for repair or replacement due to damage. In some cases the vendor (AMETEK/Straza) was consulted for possible repair but since no field repair techniques were available at the time, the line was returned to the vendor facility for replacement of the outer jacket bellows. As shown in the Task III, Sub-task 1, Phase I Technical Report of this program, most of the line failures were due to externally applied loads which were handling and operational abrasion and shock.

The study of the causes and prevention of damage to V. J. and other lines is covered by Task III, Sub-task 1, Phase I Technical Report for this program. It is therefore the intention of this Sub-task 2 portion of the program to be concerned with which types of damage are repairable or potentially repairable rather than how they were formed.

Damage must first be defined and for purposes of this study will include (a) pierced holes of all sizes in the jacket, (b) sharply defined indentations or scratches in the line jacket and (c) small holes in weld joints in hard line pipe and joints.

The conditions described were observed (usually in combinations) in many lines returned to AMETEK/Straza for repair and/or modification. A typical example of a damaged outer jacket bellows on a CO_2 jacketed flex line is shown on the following page. It can only be determined by leak testing whether a hole exists in this type of damage, however, a repair is highly desirable in any case since it forms a discontinuity in the flexible member and since it is a natural depository for contamination and subsequent corrosion. It has been established that such damage as shown can lower flexure cycle life expectancy as documented in Straza Report 8-480077 which is included as a part of this Final Report. It can be observed that the damage has flattened the crown of the convolutions to the extent that only slight flexure is sufficient to make them touch. Such distortion entraps dirt and grit and grinds it into the metal causing further damage.

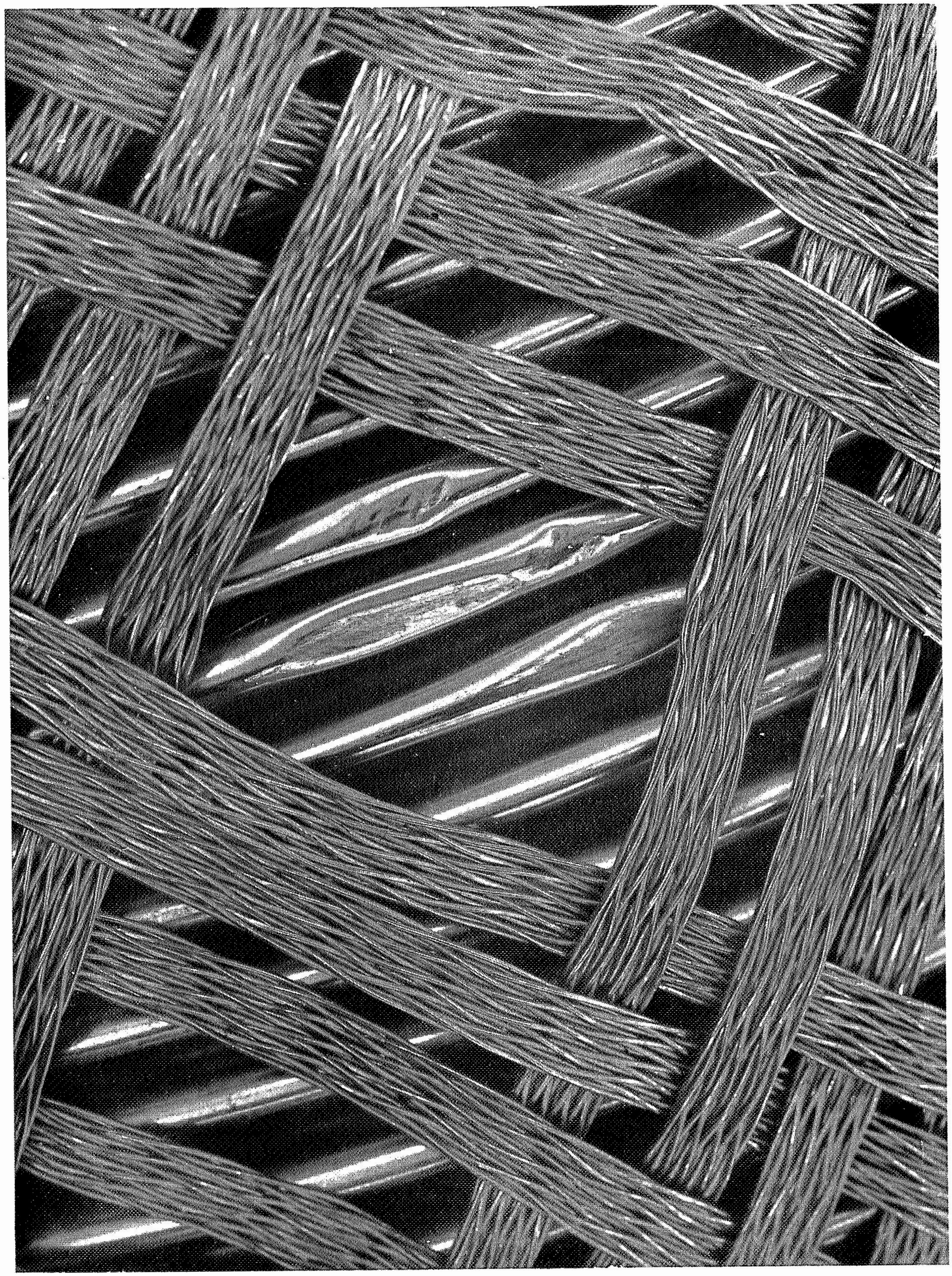


Figure 1. Vacuum Jacketed Flex Line Damage Incurred at Launch Complex 39

In view of the foregoing it is suggested that all damage to jackets should be repaired if distortion can cause further problems. Light scratches, fully radiused small dents and such do not seem significant to this study. The size of hole which can reasonably be expected to be repairable in the field is greatly dependent upon the material or method of repair. The aerosol sprays and low viscosity fluids normally used in laboratories to seal potential vacuum leakage areas are generally limited by manufacturers surveyed to 2 micron-liter per second leak rate hole sizes, which of course are microscopic. Such things as tapes, putty-like duct sealers and welded patches could be applied to much larger holes. Without specific testing of these materials and methods, definite hole size limitations cannot be firmly given. However, since it has been observed by AMETEK/Straza on a large number of lines returned from Launch Complex 39 for shop repair that the most common holes are within the range of 0.005 in. to 0.250 in.; this has been the area of concentration for this study.

3.7.2 Define Field Conditions

The conditions affecting field repairs of jacketed lines in use at Launch Complex 39 are critical to any selection of materials and methods. The salt spray atmosphere, wind, humidity and sunlight exposure are well known through years of experience by NASA and all equipment suppliers for Launch Complex 39. Any repair material considered must be resistant to these conditions. However, these well-known atmospheric factors are only a part of the environment which must be considered. On-site field inspection and study of line positions in the drawings which follow this text revealed limited accessibility for operators attempting inspection, check-out and/or repair of lines. In many cases, referring to these drawings it can be seen that access is possible only by climbing outside the service arm main walk-way. It becomes apparent, in view of the foregoing that: (a) materials of repair must be resistant to a wide range of environmental conditions, (b) that leak detection and repair equipment (if lines are to be considered installed) must be portable, and (c) that due to the height of the service arms, safety of operation must be a major consideration.

3.7.3 Leak Locating Methods

Location of outer jacket leaks on CO_2 and vacuum jacketed lines in place, that is, while the line is still part of the umbilical system, is complicated by the conditions discussed in Paragraph 3.7.2, preceding. It can be seen by the

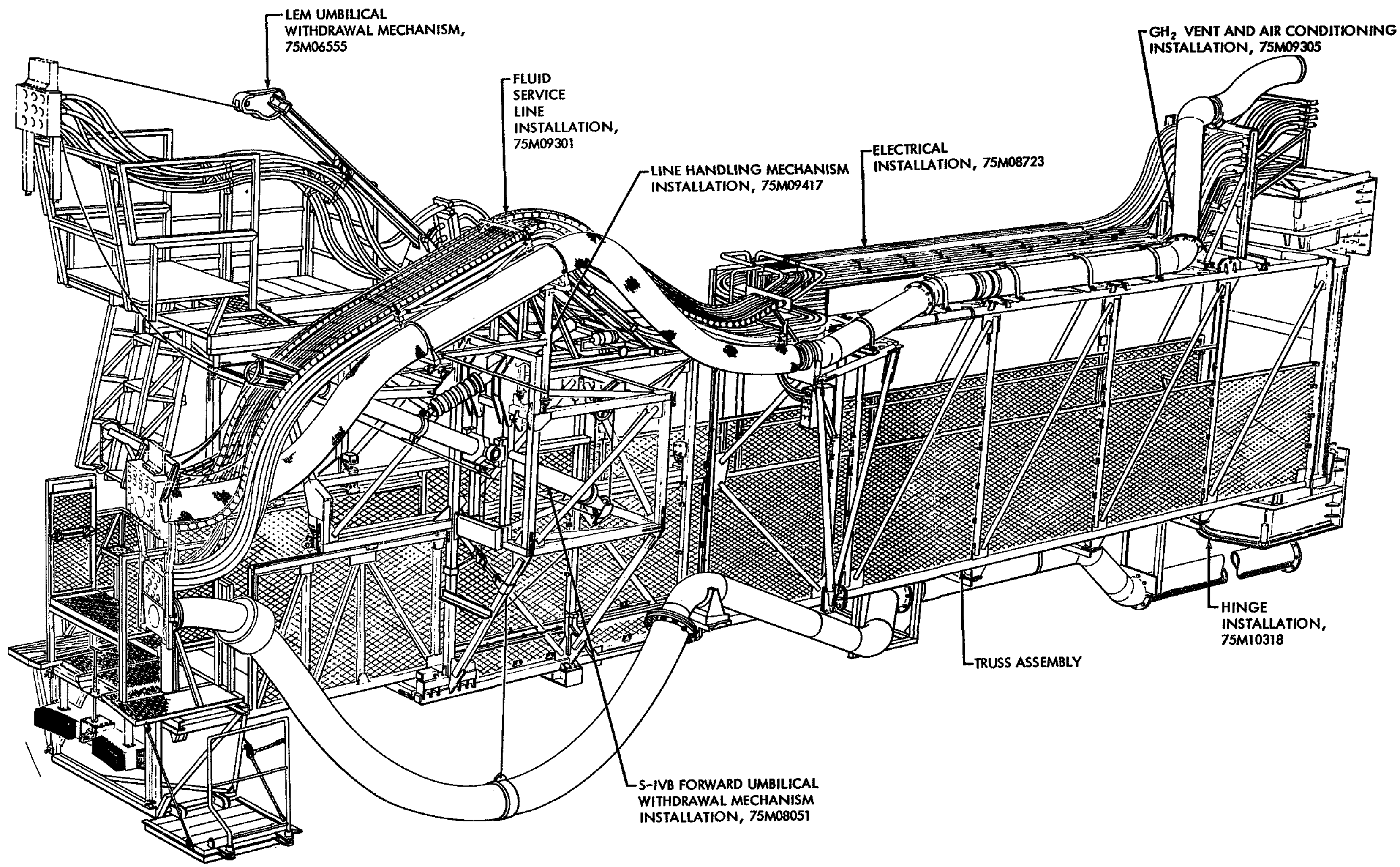


Figure 2. S-IVB Forward Service Assembly

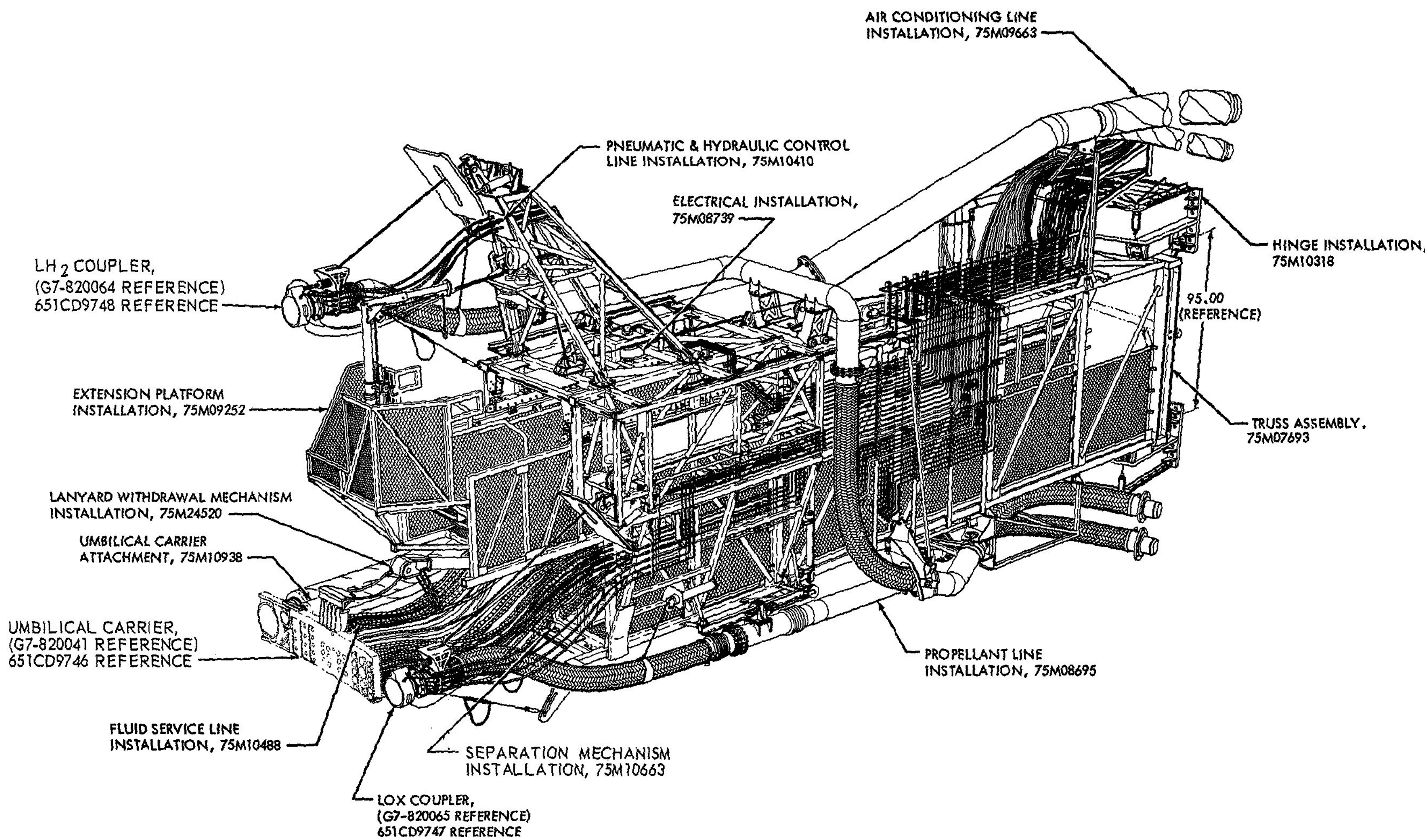


Figure 3. S-II Intermediate Service Arm

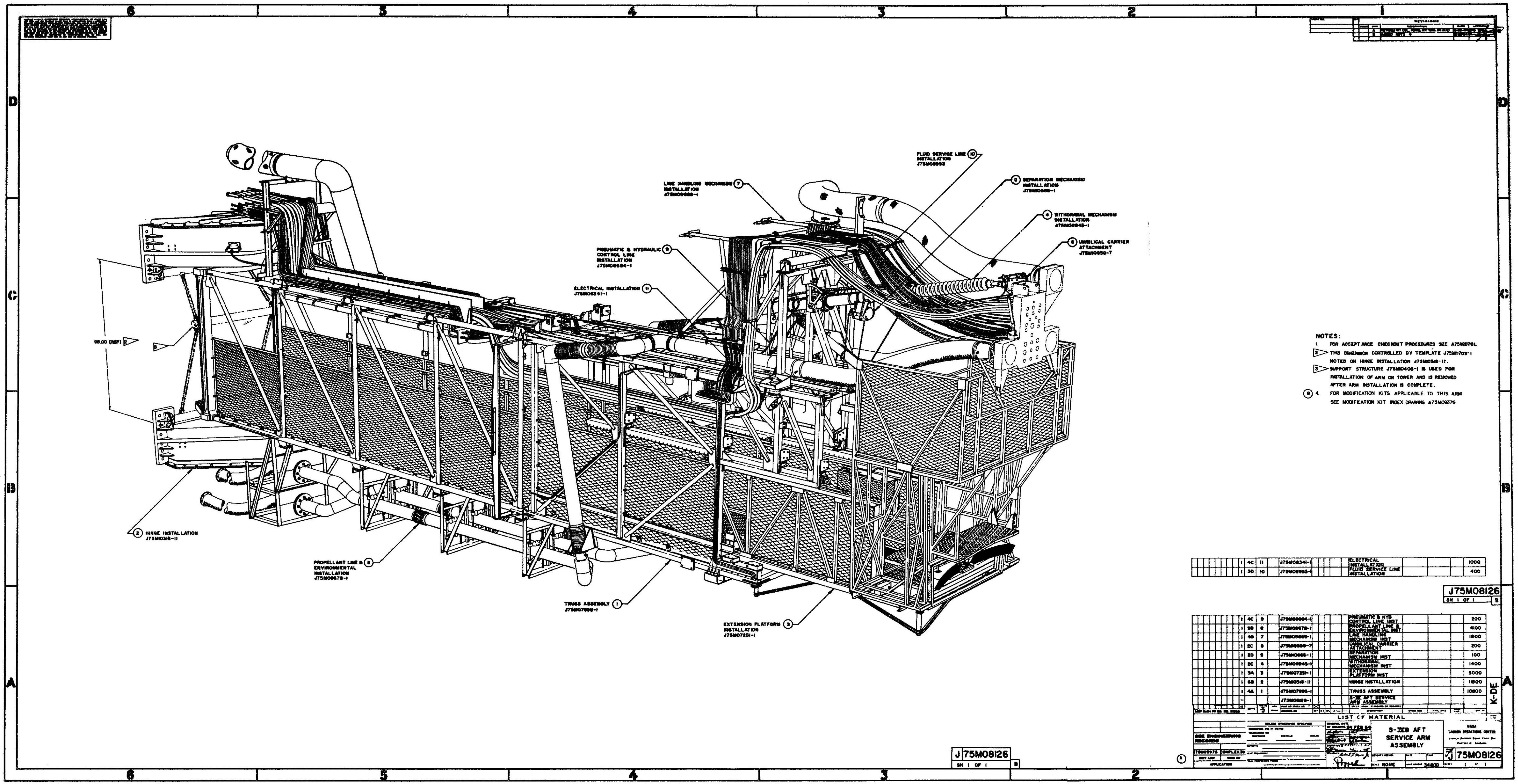


Figure 4. S-IVB Aft Service Arm

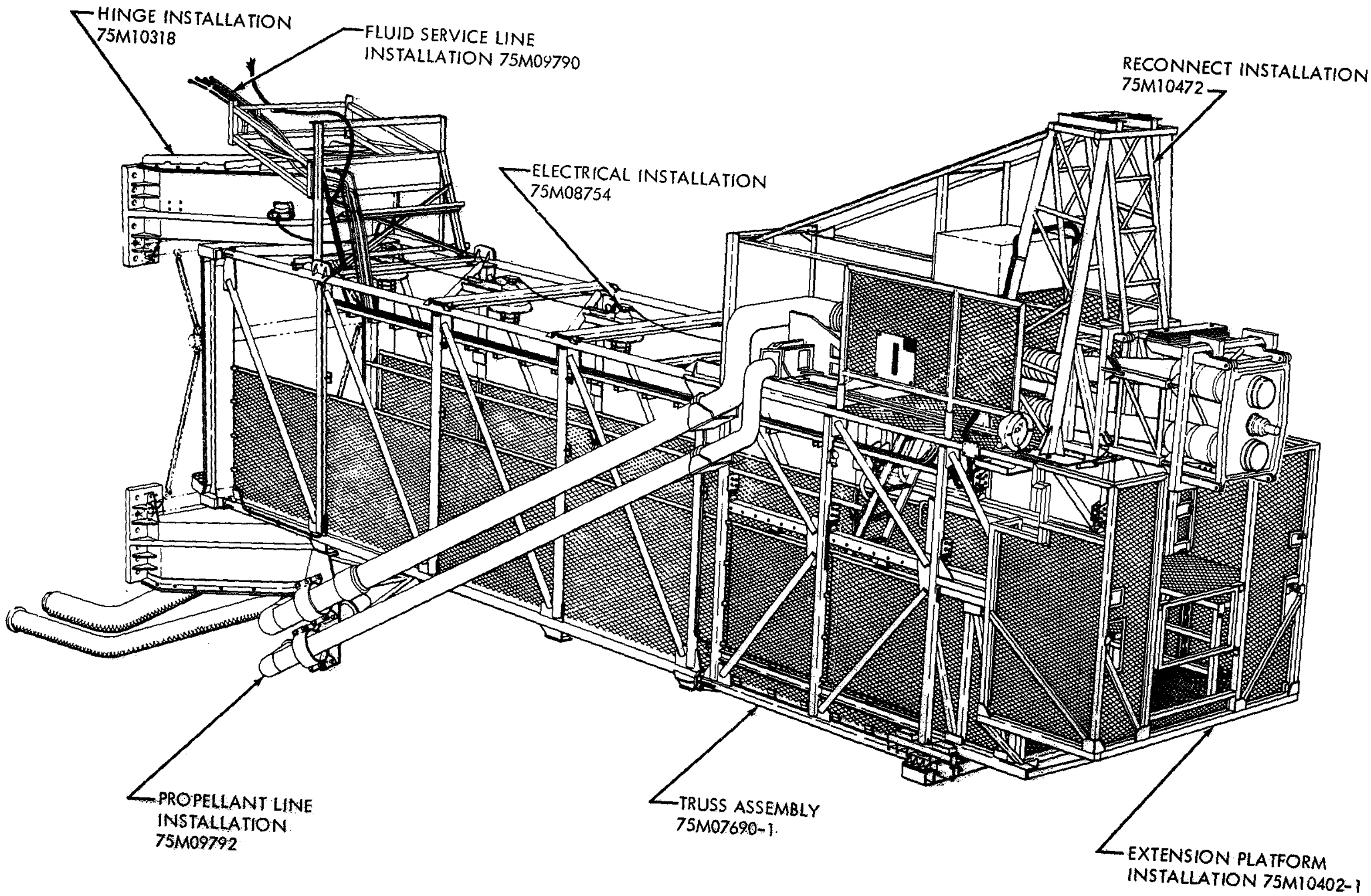


Figure 5. S-IC Intertank Service Arm Assembly

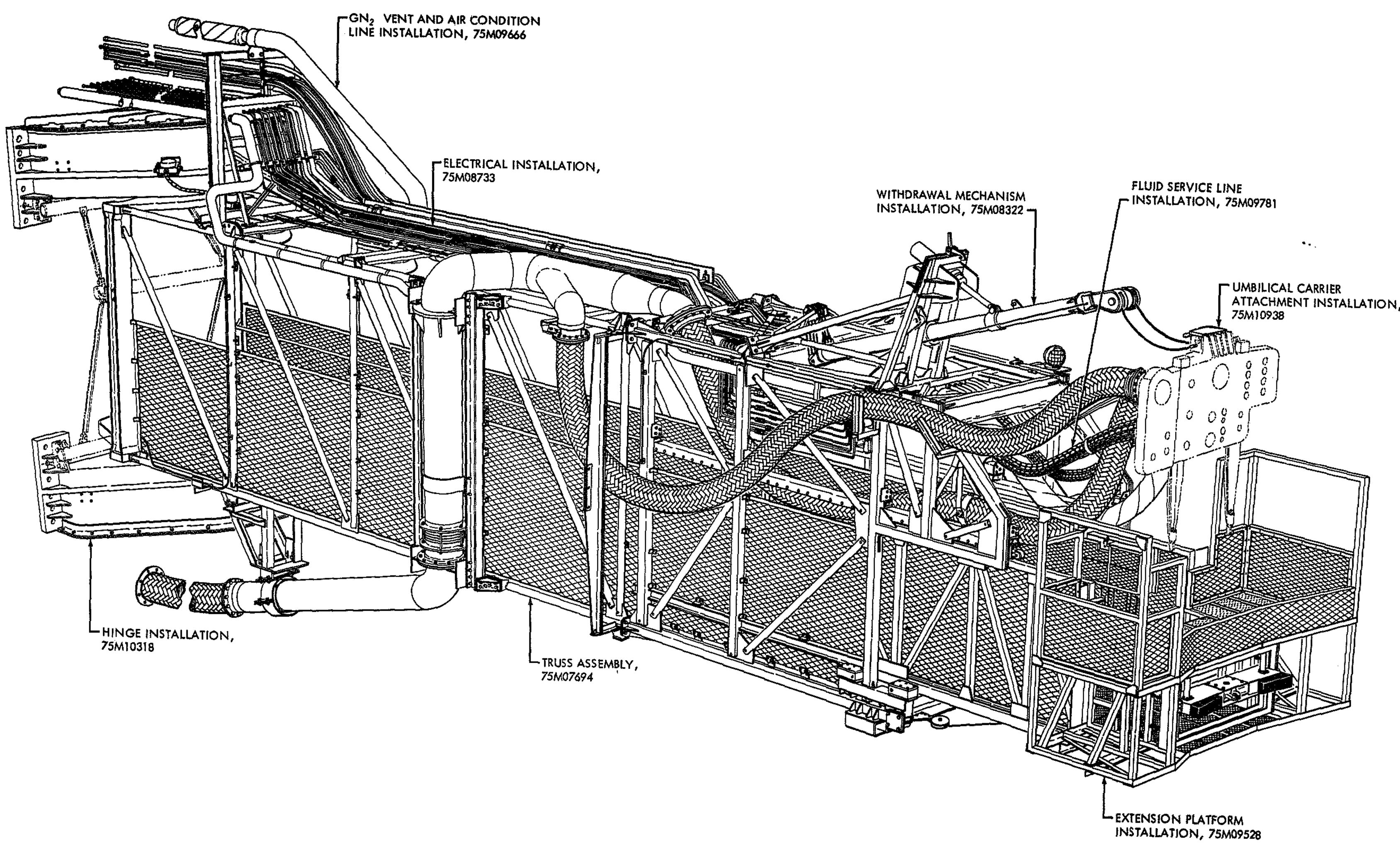


Figure 6. S-II Forward Service Arm Assembly

discussions given in Paragraph 3.7.9 (Appendix) of currently available commercial leak detection systems that most methods are oriented toward laboratory conditions.

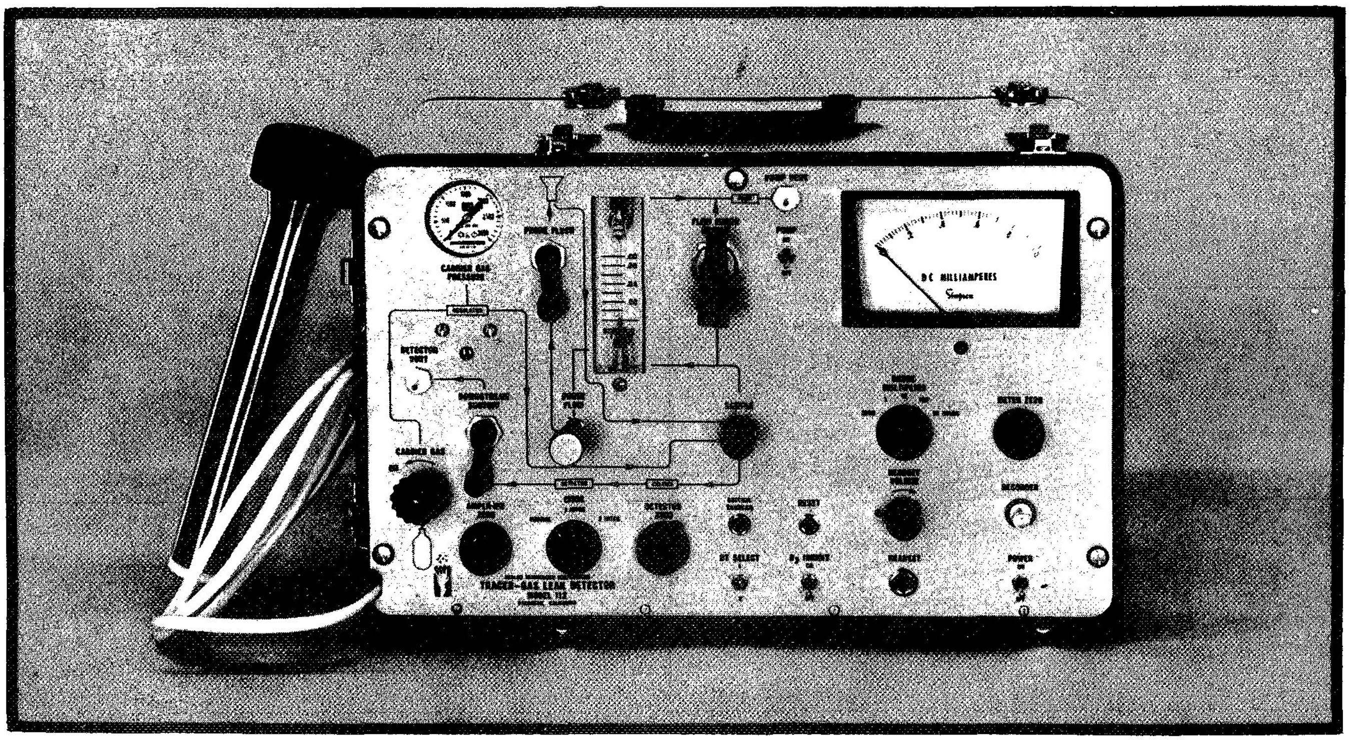
In addition, most of these methods are dependent on the leak being a very small one which would not be visually apparent. When such is the case, experience and product search efforts indicate that a mass spectrometer helium leak detection test set-up is the most efficient means of pinpointing the hole. The major drawback with this system is that the vacuum pump and electronic chassis of the system amount to a large, heavy piece of equipment not easily portable. Care must also be taken with the mass spectrometer helium leak detection system to maintain as short a hose connection as possible between the jacketed annulus pump-out valve and the vacuum pump in order to cut down on the time lag as the helium gas travels from the hole into the annulus and through the hose to the helium detector. This time lag can cause confusion as to exactly where the leak is located and also make the process a very long one. More than one leak in a given line can further complicate the process, especially if they are in close proximity to each other.

In the case of larger leaks, where a partial pressure cannot be attained with a reasonable-sized vacuum pump, other concepts of leak detection must be considered. Back-filling the CO_2 or vacuum annulus with a gas which can be detected as it exits from the hole or holes into atmosphere is one method. Many types of portable, battery operated, self-contained gas detectors are commercially available. (Three examples are illustrated on the following pages.) Such instruments could be used to pinpoint large leaks quickly if the annulus could be pressurized. The gas used to pressurize the CO_2 or vacuum annulus must be one which will not permanently contaminate the molecular sieve gettering material and also one which is easily pumped out of the system once the leak is repaired. CO_2, Argon or Freon 22 would be good candidates. Soap bubble testing is another method of gross leakage detection which can be employed on-site quickly and with a minimum of equipment. Soap bubble tests for gross leakage, mass spectrometer helium leak detection and residual gas analysis methods as employed at Launch Complex 39 by KSC service contractors are representative of state-of-the-art techniques and equipment. Although not ideal for leak detection on installed lines due to access problems, such methods are never-the-less the best presently available.

In summary, the method of leak detection should depend on the line condition. If a CO_2 or vacuum jacketed line is known to have reached atmospheric pressure in a short time (less than a week) then gross leakage is indicated and pressurizing the

A MAJOR ADVANCE IN LEAK-DETECTOR SENSITIVITY, VERSATILITY, PACKAGING AND ECONOMY

ATC's Model 112A Tracer-Gas Leak Detector* compactly packages everything necessary to detect leaks and make ultra-sensitive measurements into a fully self-contained, battery-operable, hand-portable unit comparable in volume to a small overnight case. Complete with probe, carrier-gas cylinder and two interchangeable rechargeable batteries with a total normal operating capacity of 30 hours, this remarkable unit weighs just 33 pounds. Yet, this compact, high-performance gas-chromatograph type instrument offers practical concentration sensitivities at atmospheric pressure far surpassing those of helium mass spectrometers. Concentration sensitivities of one part tracer (sulfur hexafluoride, SF_6) to 10^{11} parts of air and leak-rate sensitivities of 10^{-11} atm cc/S are entirely practical with the Model 112A. The super-sensitivity, versatility and portability of this rugged, economical device now make high-level leak detection and measurement possible for nearly every application.

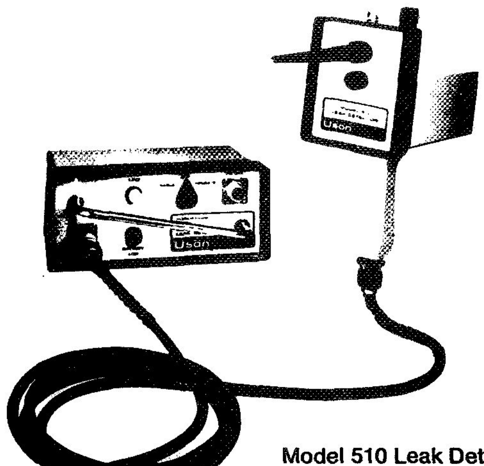


- **Unmatched Sensitivity at Low Cost** – Offers far greater sensitivity than helium mass spectrometer at a fraction of the cost. No vacuum system required.
- **Small, Light, Portable** – Overall dimensions, 16" x 12½" x 10"; weight, 33 pounds.
- **Completely Self-Contained** – Includes everything: Carrier-gas supply, two interchangeable batteries, battery-recharging circuit, probe and power cord for battery recharging or operation on conventional 110-V, 60-Hz power.
- **Multiple Leak Indications** – Contains visual leak indicator, plus outlets for a strip-chart recorder and a headset.
- **Four Operating Modes** – General detection and localization, sensitive detection and localization, sensitive leak-rate measurement, and tracer peak area measurement.

* Copyright

Figure 7. Tracer Gas Leak Detector

MODEL 510
LEAK DETECTOR



Model 510 Leak Detector
and Power Supply.

Operator Compatible
Simple-Portable
Direct Viewing

NO CONTROLS OR ADJUSTMENTS

Foolproof operation by personnel without special training is assured.

NO INTERFERENCE FROM BACKGROUND GASES

This leak detector is unaffected by the gas concentration (background) in the atmosphere. A separate reference intake and detector cancels out background gases. Loss of sensitivity and interference are prevented.

BROAD DYNAMIC RANGE

Pinpoints all sizes of leaks precisely and fast. Dynamic range of 50,000 to 1 in the three sensitivity ranges. Automatic range feature prevents loss of sensitivity as the gas concentration increases near the leak. "Ghosts" are eliminated automatically.

RELIABLE - RUGGED

Durable packaging of the solid state electronics eliminates maintenance and insures long life, even under field conditions. The stable detectors require no periodic service or replacement. One year complete service warranty on every unit.

COMPLETELY PORTABLE

The compact, lightweight unit operates directly from line power for continuous duty and also operates cordless from its rechargeable batteries for over eight hours on portable applications.

HIGH SENSITIVITY

Working sensitivity to helium, hydrogen, and Freons is 1×10^{-3} c.c./sec. full scale. For most other gases it is 5×10^{-3} c.c./sec. full scale. This practical sensitivity range exceeds soap solutions and sonic detectors by several magnitudes and is about half the sensitivity (in magnitudes) of mass spectrometer equipment. This sensitivity is unchanged with accumulation of background gas.

FAST RESPONSE AND RECOVERY

Response time is less than one second. Recovery period is only a few seconds.

TRASH - FREE SAMPLE SYSTEM

Stoppage of sample flow by suction of foreign matter is eliminated. The integral, electrically powered blower draws continuous samples by "forced draft."

BROAD SCOPE OF APPLICATIONS

The Model 510 Leak Detector is used for the inspection and maintenance of all types of pressurized equipment and systems. It is equally suited for leakage inspection on production manufacturing items or maintenance of process facilities and equipment.

Its ability to detect many different gases gives it broad versatility. Tracer gas selection for manufacturing inspection is flexible. Most gases used in process facilities are detected.

The well perfected instrument has over five years of operating experience on a broad scope of applications. This background assures you of positive application techniques.

Figure 8. USON Model 510 Leak Detector

Complete technical data on sensitivity to different gases is given in a supplemental bulletin entitled "Sensitivity Data". Comprehensive discussion on the unique design features of this instrument are in a "Special Features" bulletin. These are available on request. Application assistance is available from representatives in principal cities and the factory.

Detects Many Gases

This leak detector is sensitive to a wide range of different gases. It detects inert gases, such as helium and argon; flammable gases, like hydrogen, propane, and natural gas; corrosive gases, such as ammonia and chlorine; and others including Freons, sulphur hexafluoride, nitrous oxide, and carbon dioxide.

Any of these gases may be detected without any change to the instrument.

This versatility is due to the use of novel, temperature compensated, solid state detectors which sense the thermal conductivity characteristic of gases. Gas samples are continuously drawn through the probes by an integral pump. As they pass over the electrically heated detectors, minute changes in heat loss occur. This is caused by a gas of different thermal conductivity than the ambient atmosphere. The cooling effect on the detectors is measured electronically by a stable, high gain, a.c. amplifier.

Additional Specifications —
Model 510 Leak Detector

Ambient Temperature Range:	10°F to 130°F
Humidity Range:	0 to 100%
Warm Up Period:	30 seconds

Power Supply:
Operates directly from 100-125 vac. for continuous operation or cordless for eight hours from rechargeable batteries. Complete recharge in fourteen hours. Charger is integral. Automatic low battery light. Power cable is included.

Instruction Manual:
Comprehensive manual on operation, special application techniques, operating principles, parts lists, and troubleshooting analysis are included. Manual stores in carrying case.

Sample Probes:
8" rigid probe, 12" and 24" flexible hoses are standard.

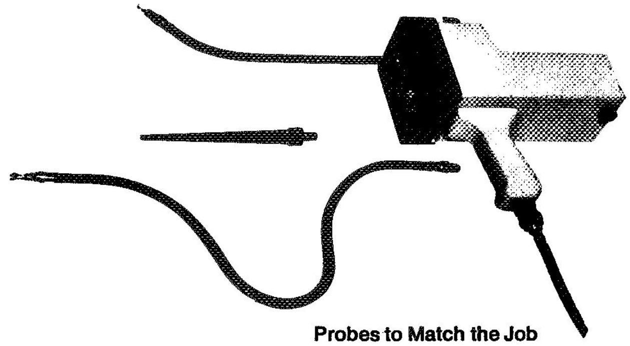
Carrying Case:
Moulded foam polyurethane lining in splash proof, heavy duty fiberglass case.

Weights:

Leak Detector Unit:	4 lbs.
Power Supply Unit:	[illegible]
Carrying Case:	[illegible]

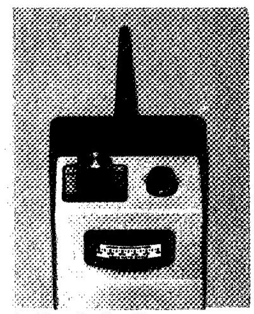
Uson Corporation
Houston, Texas

MODEL 510 LEAK DETECTOR

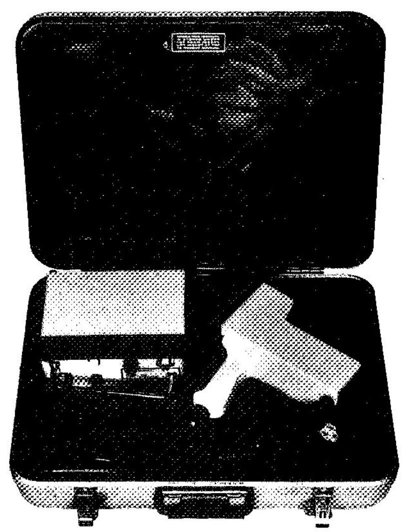


Probes to Match the Job

Differential Detector Eliminates Interference from Background Gases.

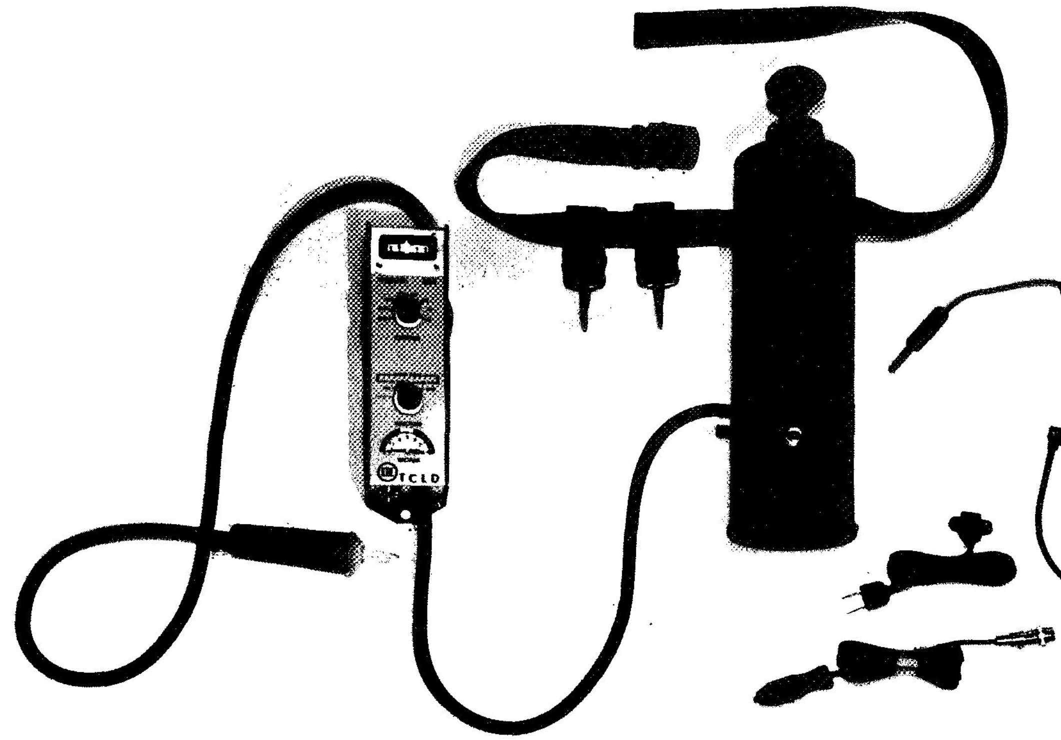


In-line Indicating Meter and Light. Convenient Range Switch.



Rugged Carrying Case with Moulded Liner.

Figure 9. USON Model 510 Leak Detector



GENERAL DESCRIPTION

TYPE 24-301

TCLD

THERMAL CONDUCTIVITY LEAK DETECTOR

The TCLD is CEC's portable leak detector designed to be used by workmen in the field. It is a rugged instrument intended for use along pipelines, on tank farms, in shop areas, in refineries and pilot plants, at missile sites — wherever mobility and precision leak detection are required.

VERSATILE, SENSITIVE DETECTOR

To achieve maximum versatility and sensitivity, the TCLD employs thermal conductivity detectors. The thermistor elements of these detectors sense changes in thermal conductivity caused by leakage gas. Thus, the TCLD is able to find and measure the approximate size of virtually any leak where leakage-gas thermal conductivity is different from that of the surrounding atmosphere. Vapor leakage also can be located, providing the vapor does not condense at or near the prevailing atmospheric temperature. Sensitivity of the TCLD is 1 x 10^{-5} atm cc/sec/meter division for helium escaping into the air (see the Sensitivity Chart for values with other gases).

DESIGNED FOR DAY-LONG OPERATION

Weight of the complete TCLD is less than seven pounds. A web belt which straps around the operator's waist makes the instrument easy to carry. The manually pumped vacuum system, which is operated while strapped on, holds an operating vacuum for ½ hour; vacuum is restored by ten to fifteen strokes of the pump. Low drain batteries, which fit into the base of the vacuum unit, power the sensing element and are adequate for the full day's operation. These nickel-cadmium batteries may be recharged an unlimited number of times, and are replaceable by the user. Recharging is done either by connecting an electrical cord to the TCLD and any 115 v, 50-60 cycle a-c outlet, or by connecting another cord to the TCLD and an automobile cigarette lighter holder. The d-c cable is usable with vehicles having a 12 volt battery (either positive or negative ground). Drain on the car battery is only 0.1% for a complete recharge of the TCLD. An internal regulator permits a recharging line to remain connected to the TCLD indefinitely without overcharging the battery pack. For round-the-clock leak testing, a duplicate battery pack may be purchased to permit charging of one unit by an accessory recharger while the other battery pack is in use.

RUGGED, PRECISION CONSTRUCTION

The solid-state electronics of the TCLD are securely mounted on heavy circuit boards and are resistant to impact, dust, or corrosion. Wiper type switches reliably assure electrical contact within the instrument regardless of operating conditions. Heavy gage aluminum is used for the control unit case and the various plastic components all have resisted the most severe impact tests devised by CEC quality control.

Performance of the TCLD electronics is commensurate with the superior grade of workmanship used to build the instrument. Baseline zero remains stable within operating limits for a full hour and is rezeroed simply by turning a knob that moves the meter needle back to zero.

QUANTITATIVE LEAK MEASUREMENTS—FAST

A significant design advantage of the TCLD is the location of the leak sensing elements inside the probe. By minimizing the distance between the leak and the detector, a 50% full scale response can be achieved in less than one second. Signal cleanup also is fast; reduction to a 5% level is accomplished in five seconds or less.

Two forms of readout are provided. An OUTPUT meter on the control unit gives a visible measurement of leakage concentration. The meter is calibrated 10 - 0 - 10 since some leakage gases register above the baseline and others below. An audible signal, monitored by the operator using the headphones provided, has variable frequency which registers the leakage gas concentration. Quantitative measurements of leakage can be made using the TCLD if the instrument first is calibrated using a standard leak.

Figure 10. CEC Portable Leak Detector

annulus would be reasonable since no vacuum pumping time or CO_2 charging time would be sacrificed. However, if the annulus has some CO_2 charge or if there is less than one atmosphere in a vacuum jacket then probably a mass spectrometer helium leak detection test would be less time consuming. The major consideration is starting from atmosphere to achieve a hard vacuum (less than one micron of mercury). This process can take anywhere from one day to one week depending on annulus volume, pump capacity and water content in annulus. The mistake of using the relatively small pump on a mass spectrometer to pump out a large volume annulus should be avoided. Large, fast, roughing pumps are available to do the main portion of evacuation on large lines and will save many manhours on-site.

The content of the vacuum annulus can sometimes be revealing as to leak location. A residual gas analysis test with a gas chromatograph will give percentages of constituent gases in the annulus. Thus, on an LH_2 line, an unusually high H_2 percentage would indicate inner line leakage, whereas N_2 concentration would indicate jacket leakage.

In summary, it is recommended, based on the findings of this study, that the following procedure be followed regarding leak detection.

A. Maintain a dated and signed history log on vacuum annulus pressure readings and CO_2 jacketed pressure charge. Notation should include dates of pumping, charging and repair.

B. When the average daily pressure rise in a vacuum annulus is greater than allowable or the CO_2 charge in a vent line deteriorates, then a leak rate test should be performed.

C. If no leakage is detected on the outer jacket of the line and it is known that other than atmospheric gas content exists in the inner line, then a residual gas analysis should be run to determine whether inner line leakage exists.

D. If the history log lists repairs to the line, these places on the line should be checked for leakage with special care.

E. After repair to line has been accomplished, baking of line to warm inner line to 350° F should accompany pump-down. This will accelerate pump-down and be insurance against subsequent out-gassing and is especially important in activating H_2O saturated getter.

Step "A" preceding is the most important and is the only way of cutting down maintenance guesswork and error. Unless a history of annulus pressure, rework, pump-down, repair and testing is available, then hours can be wasted in extra steps during the process of determining leakage and making repairs.

3.7.4 Repair Methods and Materials

Once a leak (or leaks) has been determined to exist in a line the decision must be made as to whether it can be tolerated. In order to make this decision an understanding of the cryo-pumping efficiency of the system is essential. Cryo-pumping in the vacuum annulus (or CO_2 filled annulus) is defined as condensation of gaseous constituents contained in the annulus as the temperature drops from ambient to cryogenic during chill-down (filling) of the line. Some of the gases (such as O_2 and N_2) will condense at a higher temperature than others (such as H_2 and He). Thus, when a V. J. line is chilled with LH_2, the H_2 in the annulus is much less a problem than if the system were chilled with LN_2 or LO_2. From the foregoing it can be seen that a residual gas analysis of the annulus constituents can, in some cases, serve to predict cryo-pumping performance. However, with a molecular sieve (getter) properly placed against the cold wall in the annulus and used in sufficient quantity there should be no problem unless the annulus has filled with atmospheric constituents through leakage past the point of cryo-pumping and/or sorption efficiency. Sorption takes place as gases are trapped in the getter. Even this process is enhanced by lowered temperature. It can be seen from the figure on Page 16 that in order to achieve an efficient insulation the pressure in a vacuum annulus must be on the order of 0.10 micron of mercury when chilled. However, the pressure at ambient temperature can be much greater due to the anticipated cryo-pumping action as discussed. Some test results are given in the figures on Page 17 and 18 showing a Pressure/Time plot during chill-down from 2000 microns of mercury with Zeolite 5A getter and starting at 4000 microns of mercury with charcoal getter. The Page 17 figure depicts a test conducted to determine the amount of getter required for a given annular space volume. The bare minimum was used and for this reason the cryo-pumping action leveled off at about 0.18 microns of mercury. In the figure on Page 18, however, are the results of a test run with a production V. J. line as used on the cross-country piping in the LH_2 system on Launch Complex 39B. Since a generous amount of getter was employed, it can be seen that cryo-pumping and sorption was efficient down to 0.05 microns of mercury. If the proper amount of getter is used in a V. J. line there should be no problem cryo-pumping from a pressure of 4000 microns or even 8000 microns assuming

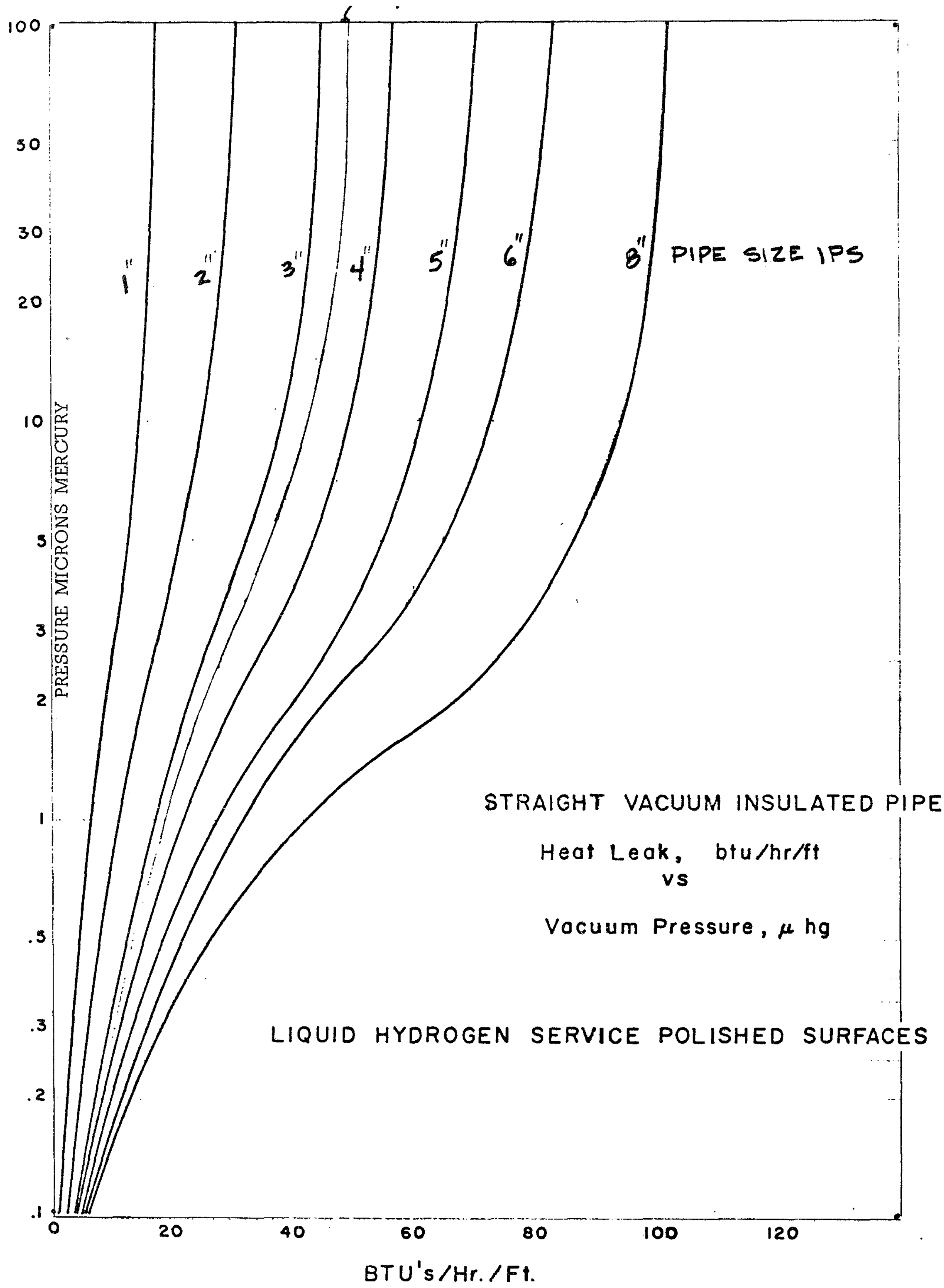


Figure 11. Heat Leak Rate Graph

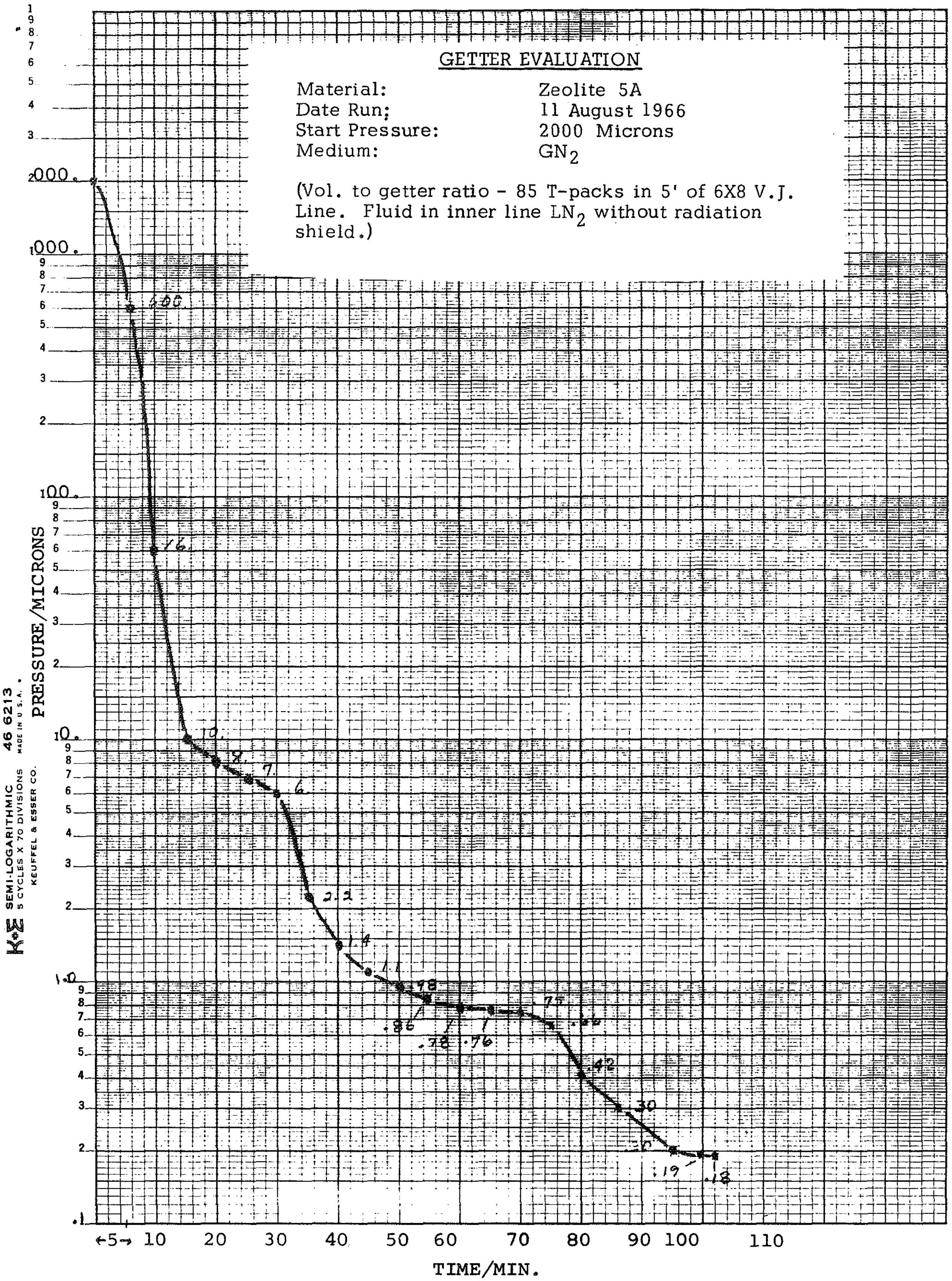


Figure 12. Getter Evaluation Graph - Zeolite

the gas constituents in the annulus either are capable of being condensed at the chill-down temperature or absorbed by the getter. Using the foregoing information as the basis for determination of a maximum allowable leakage rate and maximum allowable pressure in the annulus of a jacketed cryogenic line is a logical next step. Assuming the pressure in the annulus of a fairly large line (such as are used at Launch Complex 39) is at 200 microns of mercury and rising at a rate of ten microns per day, it would be more than a year before it would reach 4000 microns and be at a point where it would require repumping. Thus, if a one-year service interval can be accepted, a ten micron per day pressure increase allowable would seem reasonable.

Once it is determined (a) that the leakage rate of a line is too high to be tolerated, (b) where the leak is located, and (c) that it is desirable to repair in place rather than remove from the system, then a number of repair materials and methods are available. The following investigation and analytical results are the culmination of Phase I of the Vacuum and CO_2 Jacketed Line Repair Technique Study.

3.7.5 Literature Research

The major drawback of welding processes for field repairs are: (a) Possible damage to annular space components such as Teflon spacers and radiation shielding, (b) large, heavy power supply equipment necessary to welding, and (c) dependence on highly skilled operator and his technique, particularly on thin wall bellows. Despite these apparent shortcomings, literature on welding technology was surveyed and analyzed with emphasis on seeking out new developments which might at least partially overcome these problems. Many methods of metal fusion were studied. Electron beam welding, although very precisely controllable as to heat input, requires massive equipment. Tungsten electrode, gas shielded arc, oxyacetylene coated wire and all similar methods share the common problems enumerated above in (a), (b), and (c). Laser beam, thermite and microwave processes, in addition to being experimental, also involve non-portable equipment. Thus, it has been concluded for this study that welding methods hold little promise as field repair methods which could be basic improvements in state-of-the-art.

In view of the foregoing, more emphasis was placed on researching moderate, low and no-heat methods of repair. Although some of the same heat and equipment problems are common to welding and brazing, the latter was thoroughly investigated.

Brazing (or silver soldering) is a commonly employed method of joining stainless steel where the void area is small. Some promise was found for repair applications for the lower melting temperature silver alloys (eutectic) presently in use industrially. Soft solder is another step down the heat range ladder from brazing and for small pin holes in pipe or bellows appeared to be of value for repairs. The non-metallic, "low" and "no" heat methods were studied most carefully and intense effort was made to uncover new and/or better repair materials in these categories. Many liquid sealants of known properties were evaluated, however, it was in the area of materials not normally used for this work that the most time was spent in literature search.

Trade magazines such as "Vacuum Technology", "Research and Development", "Materials Engineering", "Industrial Research" and "Environmental Quarterly" were surveyed for articles and advertising on product, materials, and methods pertaining to vacuum leak repairs. Where it was possible, literature was requested from vendors. Some of this literature and advertising is included on the following pages.

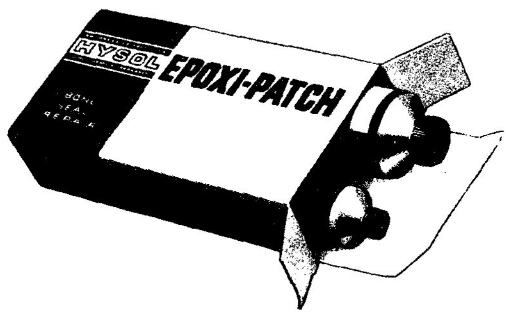
Figure 14. EPO Mold Seal

PROGRESSIVE PRODUCTS HYSOL THRU CHEMICAL RESEARCH

ADHESIVES, SEALANTS & COATINGS
TECHNICAL DATA

BULLETIN NUMBER **A3-201A**

GENERAL PURPOSE
Epoxi-Patch Kits 1C and CK1A



- 100% Solids
- Room Temperature Cure - May Be Heat Accelerated
- High Strength
- Versatile - "Anything to Everything"

1.0 Description

1.1 The 1C kit is a general purpose room temperature curing adhesive/sealant that bonds a wide variety of surfaces. This two-part system is relatively insensitive to mixing ratio or substrate cleaning procedure. Since there are no solvents, there is no fire hazard. It is non-toxic when cured. It is widely used for bonding, sealing and repairing metal, wood, rubber and most plastics. It can be sanded, cut, tapped and machined.

1.2 The CK1A kit is a small, handy version of the 1C with slightly lower viscosity.

2.0 Typical Cured Characteristics - Values are average, based on several determinations, and are not intended for use in preparation of specifications.

2.1 PHYSICAL

	1C	CK1A
Tensile shear, psi, MIL-A-8623 @-50°F (-46°C)	2,144	2,175
Tensile shear, psi, MIL-A-8623 @77°F (25°C)	1,900	1,850
Tensile shear, psi, MIL-A-8623 @77°F (25°C) (after 70 days @90-95% R.H. @150°F (65°C)	1,600	1,850
Tensile shear, psi, MIL-A-8623 @180°F (83°C)	800	800
Water absorption, %, 24 hours immersion	0.30	0.27
Linear shrinkage, %, 77°F (25°C)	0.70	0.65
Flexural strength, psi	11,000	11,000
Compressive strength, psi	10,000	10,000
Shore D hardness	75-80	75-80

(over)

DEXTER
HYSOL DIVISION • THE DEXTER CORPORATION
DIVISION HEADQUARTERS: OLEAN, NEW YORK 14760 PHONE: 716-372-6300
MANUFACTURING FACILITIES: OLEAN, N.Y., LOS ANGELES, CALIF., TORONTO, ONTARIO, LONDON, ENGLAND, MUNICH, GERMANY

Figure 15. HYSOL Adhesives

Vacuum Products

SYSTEMS • COMPONENTS • INSTRUMENTS
ANALYTICAL MEASUREMENT BUSINESS SECTION
SCHENECTADY, N. Y. 12305

ULTRA-HIGH VACUUM LEAK SEALER

GEVAC* Vacuum Leak Sealer provides permanent sealing of leaks in high and ultra-high vacuum systems. It is a silicone resin in a Xylol solvent and, when applied properly, will assure permanent sealing of small, troublesome leaks.

The Sealer may be applied to any material with equal effectiveness. Application is a simple three-step procedure of (1) cleaning the surface, (2) applying the Sealer with the enclosed brush, and (3) curing the Sealer. For small leaks (one micron-liter/second or less), Sealer may be applied while the system is under vacuum. Heating at 200 C for one hour with a heat-gun (or other means) will provide sufficient curing.

For larger leakage, the Sealer must be applied when the system is at atmospheric pressure. As stated above, curing for one hour at 200 C will assure a permanent seal. Curing may be carried out at lower temperatures by extending the heating time.

Vacuum Leak Sealer is a liquid requiring no mixing or preparation. Its low viscosity assures penetration into

the smallest leaks. Repeated bakeout up to 300 C will not affect it, and it serves as an excellent electrical insulator with a dielectric constant of 2.9 to 3.3. When cured, its vapor pressure is sufficiently low to assure that the prior system base pressure can again be obtained.

To order, or for more information on G-E Vacuum Leak Sealer, write to General Electric Vacuum Products Operation, Building 28, Schenectady, New York 12305

* Trade-mark of General Electric Co.

ANALYTICAL MEASUREMENT BUSINESS SECTION
GENERAL ELECTRIC
SCHENECTADY, N. Y. 12305

10-68 (1M)

Figure 16. GE Vacuum Leak Sealer

High Vacuum Greases and Leak Sealants

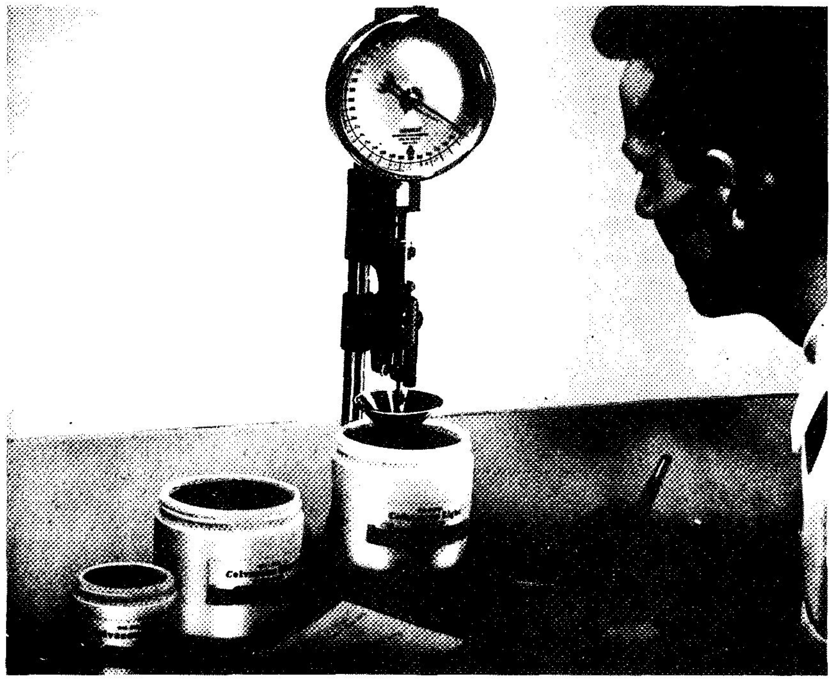
Vacuum Greases

The formulation of CVC Celvacene® grease results from three decades of high-vacuum experience. The grease is available in three viscosities.

Celvacene-Light is a pale yellow transparent grease with a melting point of 90°C and an ASTM penetrometer dial reading of approximately 150. Celvacene-Light is recommended for ground-glass joints and other vacuum seals where both lubrication and low vapor pressure are required. On continuously evacuated systems, pressures of 10^{-6} torr or less can be obtained using this grease. For best results, ground-glass surfaces should be lapped together and only a thin film of grease applied.

Celvacene-Medium is a brownish-yellow transparent grease slightly heavier than Celvacene-Light, with a melting point of 120°C. Its ASTM penetrometer dial reading is approximately 95. It is recommended for ground-glass joints and other vacuum seals under conditions where a lighter grease might be sucked through. This grease is especially useful for treating rubber gaskets, stoppers and tubing to form a vacuum-tight bond with metal or glass surfaces. Rubber thus bonded is easily removed by feeding castor oil between the surfaces with a thin-bladed instrument. The vapor pressure of Celvacene-Medium is relatively low and, on continuously evacuated systems, pressures of less than 10^{-6} torr can be obtained.

Celvacene-Heavy is a dark yellow-brown transparent grease with the consistency of a soft wax. The ASTM penetrometer dial reading for Celvacene-Heavy is approximately 60. Its melting point by the drop-from-thermometer method is 130°C. This material is recommended for surface-treating rubber gaskets and tubing for vacuum-tight bonds to metal or glass, and for use around cracks and porous spots in vacuum systems as a temporary seal. Celvacene-Heavy is easily removed from glass and metal with chloroform or acetone.



ORDERING INFORMATION

Celvacene-Light	¼ lb. 1 lb. 25 lbs.	269352-1 269352-2 269352-3
Celvacene-Medium	¼ lb. 1 lb. 25 lbs.	269352-11 269352-12 269352-13
Celvacene-Heavy	¼ lb. 1 lb. 25 lbs.	269352-21 269352-22 269352-23

Bendix Vacuum Division

Figure 17. BENDIX Vacuum Grease

PRODUCT DATA CHART

THREAD LOCKING APPLICATIONS

	PRODUCT CATALOG NUMBER	PRODUCT	CURE TIME Unprimed hrs. (1)	CURE TIME Primed Min. (2)	STATIC SHEAR STRENGTH (3) (PSI)	PREVAILING FRICTIONAL STRENGTH (4) (PSI)	VISCOSITY (CP)	MAXIMUM CLEARANCE FILLED	COLOR CODE (LIQUID)	RECOMMENDED APPLICATION EQUIPMENT (7)	PAGE
Locks studs into tapped holes; provides maximum locking on nuts and screws where disassembly is not required. Provides maximum breakaway.	73	Stud Lock	1-2	5-20	———	750-1000	400-1200	.015"	RED	Disc Coater #600 Applicator #200	7
Locks nuts, prevents vibration loosening, permits removal.	74	Nut Lock	1/4-2	5-20	———	300-400	100-150	.005"	BL[illegible]	Nut Treater #2200	8
Locks medium to long length screws, prevents vibration loosening, permits adjustment and removal.	59	Screw Lock	1/4-2	5-20	———	150-200	100-150	.005"	PURPLE	Disc Coater #600 Screw Treater #700	9

RETAINING APPLICATIONS

	PRODUCT CATALOG NUMBER	PRODUCT	CURE TIME Unprimed hrs. (1)	CURE TIME Primed Min. (2)	STATIC SHEAR STRENGTH (3) (PSI)	PREVAILING FRICTIONAL STRENGTH (4) (PSI)	VISCOSITY (CP)	MAXIMUM CLEARANCE FILLED	COLOR CODE (LIQUID)	RECOMMENDED APPLICATION EQUIPMENT (7)	PAGE
Makes anti-friction bearing fits more reliable; restores fits to worn housings. Prevents fretting corrosion.	72	Bearing Mount	1/4-4	5-30	375-1300	———	100-150	.005"	YELLOW	Roll Coater #550 Applicator #200	10-11
Bonds parts to shafts; Bonds threaded parts permanently; High strength adhesion for bonding rigid, smooth cylindrical parts.	75	Retaining Compound 75	1/4-4	5-30	2000-5000	———	100-150	.005"	GREEN	Auto Bonder #360 Applicator #200	12-13
Retains bushings with slip fit, prevents bushing spin-out. Bonds oilized bearings. Restores fit to worn housings.	43	Bushing Mount	1/4-4	5-30	2000-5000	———	100-150	.005"	GREEN	Roll Coater #550	14
Provides leak-proof seal around outer case of shaft oil seals; Flexible low strength adhesion for bonding and sealing of sheet metal parts.	44	Oil Seal Retainer	12-24	10-60	200-600	———	700-2000	.010"	PURPLE	Roll Coater #550	15
Strengthens keys and fixed-spline connections. Prevents backlash, wallowing and fretting corrosion.	42	Key Fit	12-24	10-60	500-1750	———	1000-3000	.015"	BLUE	Applicator #200 or Tumbler #700	16

SEALING APPLICATIONS

	PRODUCT CATALOG NUMBER	PRODUCT	CURE TIME Unprimed hrs. (1)	CURE TIME Primed Min. (2)	STATIC SHEAR STRENGTH (3) (PSI)	PREVAILING FRICTIONAL STRENGTH (4) (PSI)	VISCOSITY (CP)	MAXIMUM CLEARANCE FILLED	COLOR CODE (LIQUID)	RECOMMENDED APPLICATION EQUIPMENT (7)	PAGE
Seals threaded joints up to 3 diameter; seals to burst pressure of pipe; locks elbows at any angle. Contains filler to provide immediate sealing.	70	Filled Pipe Sealant	12-24	10-60	———	75-100	Paste	.020"	BROWN	Sealant Dispensing Gun #925 Controlled Metering Control #930	18
Seals and locks hydraulic and pneumatic fittings, seals all fluids. Contains no particles to foul valves.	69	Hydraulic Sealant	1/4-2	5-30	———	300-500	300-900	.015"	BROWN	Applicator #200 Disc Coater #600	19
Seals all refrigerants, strong chemicals. Locks fittings at any angle.	54	Refrigerant Sealant	4-12	10-60	———	750-1000	1000-3000	.015"	RED	Disc Coater #600 Applicator #200	20
Seals flange joints, replaces soft gaskets. Contains filler to provide immediate sealing. Low adhesion permits rapid disassembly.	49	Plastic Gasket	12-24	10-60	1600-3400	———	Paste	.020"	ORANGE	Sealant Dispensing Gun #925 Metering Control #930	21
Joins metal tubing and fittings without brazing or welding; Bonds smooth thin wall cylindrical parts which may flex in service.	60	Tube Sealant	USE PRIMER	10-60	2000-5000	———	1000-3000	.015"	GREEN	Applicator #200	22
Seals weld porosity; Resists high pressures and solvents; Prevents tank and pipe lines from leaking.	46	Weld Sealant	4-12	5-30	———	———	10-15	.003"	CLEAR	Applicator #200	23

LETTER (MILITARY) GRADE APPLICATIONS (8)

	PRODUCT CATALOG NUMBER	PRODUCT	CURE TIME Unprimed hrs. (1)	CURE TIME Primed Min. (2)	STATIC SHEAR STRENGTH (3) (PSI)	PREVAILING FRICTIONAL STRENGTH (4) (PSI)	VISCOSITY (CP)	MAXIMUM CLEARANCE FILLED	COLOR CODE (LIQUID)	MILITARY SPECIFICATION NUMBER	
For maximum locking of fine threads, for very short engagement ratios; for sealing porosity.	89	AA	1/4-2	10-20	———	1150-1500	10-15	.003"	GREEN	MIL-S-22473 C	GRADE AA
To lock fine threads; to seal fine threads.	88	A	2-6	5-20	———	750-1000	10-15	.003"	RED	MIL-S-22473 C	GRADE A
For high strength locking of threads; to seal joints.	87	AV	2-6	5-20	———	750-1000	100-150	.005"	RED	MIL-S-22473 C	GRADE AV
For high strength locking of coarse threads; to retain worn parts; to seal large thread sizes.	86	AVV	4-12	15-20	1600-3400	750-1000	1000-3000	.015"	RED	MIL-S-22473 C	GRADE AVV
A general purpose sealant covering a wide range of locking, retaining and sealing applications.	85	B	1/4-2	10-20	375-1300	525-750	100-150	.005"	YELLOW	MIL-S-22473 C	GRADE B
Locking fine threads subject to removal; for sealing small fittings.	84	C	2-6	5-20	———	300-400	10-15	.003"	BLUE	MIL-S-22473 C	GRADE C
For moderate locking of threads, for sealing fittings.	83	CV	2-6	5-20	———	300-400	100-150	.005"	BLUE	MIL-S-22473 C	GRADE CV
For moderate locking of larger threads; for sealing larger fittings.	82	CVV	4-12	5-20	———	300-400	1000-3000	.015"	BLUE	MIL-S-22473 C	GRADE CVV
For locking long fine-threaded screws, permits resetting of adjustment screws.	80	E	2-6	5-20	———	150-200	10-15	.003"	PURPLE	MIL-S-22473 C	GRADE E
For locking long screws; permits re-adjustments.	79	EV	2-6	5-20	———	150-200	100-150	.005"	PURPLE	MIL-S-22473 C	GRADE EV
For locking long small diameter screws with fine threads; seals out corrosion; permits easy removal.	78	H	2-6	5-20	———	75-100	10-15	.003"	BROWN	MIL-S-22473 C	GRADE H
For locking long screws; prevents "freezing" by sealing out moisture; permits easy removal.	77	HV	2-6	5-20	———	75-100	100-150	.005"	BROWN	MIL-S-22473 C	GRADE HV

ADHESVE APPLICATIONS

	Adhesive Identification	Cure Speed	Lap Shear Strength (PSI) (5)	Viscosity (CP)	Color	MILITARY SPECIFICATION NUMBER	PAGE
Joining "O" Rings, Attaching Labels, Name Plates, Medallions, Rubber.	Quick-Set Adhesive 404	SECONDS TO MINUTES	2000 MIN.	70-110	CLEAR	MIL-A-46050 A	30
Bond Wood, Metal, Most Plastics, Ceramics, Concrete, Glass.	Mixer-Cup of Epoxy Adhesive 2508	FULL CURE 24 HRS.	2000-3000 MIN. (6)	PASTE	RESIN — BLUE HARDENER — AMBER	———	32

NOTE: (1) Speed of cure depends on several variables, including the catalytic activity of the surface of the parts. The cure speed figures in this table are for machined steel. For further information turn to page 25.

(2) Speed of cure figures on this table are for Locquic Primer Grade T on carbon steel and cover a range of strength from finger tightness to 60% cure. This is sufficient strength to return parts to service.

(3) As measured on rigid cylindrical parts. Rough surfaces will have higher shear strengths than smooth surfaces. Range covers 5 — 125 micro inch finishes.

(4) A measure of prevailing torque; frictional force per unit area for threaded fasteners.

(5) As measured per ASTM-D1002-64. (6) Depending on surface preparation.

(7) For further information turn to pages 37 and 38.

(8) Historically Loctite letter grade products have been used for military or industrial specification applications.

Figure 18. LOCTITE Product Chart

Johns-Manville SEALING COMPOUNDS—Permanently Plastic

	STANDARD DUXSEAL ®	TYPE N & N S DUXSEAL	R-100 DUXSEAL	STANDARD NODRSEAL ®	TYPE T NODRSEAL	UNISEAL ®
USES	For sealing around wires and cables at duct entrances. A good general purpose sealer because of adhesion, shape retention and negative corrosive action on materials in contact. Used to fill in interstices in cables.	Type N is a modification of Standard Duxseal specifically formulated for Navy cable manufacture. Cables made with Type N Duxseal show good results on cable "drip test." Type NS is a softer compound for use on Navy cable. Its consistency is same as Standard Duxseal but has been *compounded to* pass Navy "drip test."	Better handling properties than Standard Duxseal. Skins faster thus enhancing paintability.	An odorless compound for use in the refrigerator industry where the dark color is not objectionable. An excellent general purpose sealer with a wide temperature range. Best aging characteristics. Most economical.	Stiffer consistency and better adhesion than Standard Nodrseal. An excellent general purpose sealer. Specially formulated to provide tight seal in presence of gas or fluid pressure.	A general purpose sealer with good weathering properties. It is similar to Nodrseal; very tacky and tough. Uniseal is used in chlorine cells in the presence of alkalies.
RECOMMENDED FOR SEALING AGAINST OR IN CONTACT WITH	Air (Dust & Moisture) Inert Gas Water (fair)	*Air (Dust & Moisture)* Inert Gas Water High Viscosity Oil (moderate)	Air (Dust & Moisture) Inert Gas Water	Air (Dust & Moisture) Inert Gas Water *Dilute Alkalies*	Air (Dust & Moisture) Inert Gas *Water*	Air (Dust & Moisture) Inert Gas Water *Dilute Alkalies*
COLOR	Gray-Green	Gray-Green	Gray-Green	Dark Brown	Black	Dark Brown
VEHICLE (BASE)	Vegetable Oil	Vegetable Oil	Resinous	Mineral Oil	Mineral Oil	Mineral Oil
ODOR	Very *slight* Castor Oil	Slight Castor Oil	Slight Semi-Sweet	None	None	*Slight Mineral Oil*
CONSISTENCY (PENETRATION) Measured by ASTM D5-52 or ASTM D-217-52T AS NOTED CONDITIONS: 5 sec; 77F; Load shown.	(50 gram load) 75-115 —	Type N (50 gram load) 60-95 Type NS *(50 gram load)* 75-125	(50 gram load) 50-80 —	(50 gram load) 90-115 —	(50 gram load) *45-75* —	(50 gram load) 65-115 —
APPROX. WEIGHT—LBS. PER GALLON	13.4	Type N 12.7 Type NS 11.8	13.2	12.3	13.1	12.3
TEMPERATURE RANGE MAXIMUM—CONTINUOUS BRIEF PERIODS MINIMUM	125F 200F —35F	125F 200F —35F	120F 190F —35F	180F 250F —35F	180F 250F —35F	180F 250F —35F
EXTRUSION CHARACTERISTICS (KNIFE GRADE) (MINIMUM SIZE)	1/4" Diam. Beads 1/8" Thick Ribbons Soft but satisfactory with proper packaging	1/4" Diam. Beads 1/8" Thick Ribbons Soft but satisfactory with proper packaging	1/4" Diam. Beads 1/8" Thick Ribbons Soft but satisfactory with proper packaging	1/8" Diam. Beads 1/16" Thick Ribbons Excellent; can be folded	1/8" Diam. Beads 1/16" Thick Ribbons Excellent; can be folded	1/4" Diam. Beads 1/8" Thick Ribbons Brittle
WEATHERING AND AGING	Good with skin hardening in 3 to 6 months	Good with skin hardening in 3 to 6 months	Good with skin hardening in 2 to 4 months	*Excellent* No skin hardening	Excellent No skin hardening	Excellent No skin hardening
ADHESION TO WOOD, GLASS, PLASTICS, METAL, RUBBER, PAINTED SURFACES	Good	*Good*	Good	Good	Outstanding	Good
CORROSIVE ACTION ON OR DETERIORATION OF STEEL COPPER BRASS ALUMINUM RUBBER PAINTED SURFACES WOOD	None None None None None *None* None	None None None None None None None	None None *None* None None None None	None None None None Plasticizes Stains some types None	None None None None Plasticizes (slightly) Stains some types None	None None None None Plasticizes Stains some types None
STAINING EFFECT AND AFFINITY FOR PAINT	Can be painted with most common paints and enamels. Won't stain hands or surfaces in contact.	Can be painted with most common paints and enamels. Won't stain hands or surfaces in contact.	Can be painted with most common paints and enamels. Won't *stain hands or* surfaces in contact.	Can be painted with most paints and enamels after priming. Stains hands but is easily *washed off with soap* and water.	Can be painted with most *paints and enam*els after priming. Stains hands but is easily washed off with soap and water.	Can be painted with *most paints* and enamels after priming. Stains hands but is easily washed off with soap and water.

	TYPE H NAVASEL ®	TYPE HF NAVASEAL	TRANOLSEAL ®	ALBASEAL	TYPE A BODY SEALER TYPE B BODY SEALER	VOLSEAL
USES	For sealing electrical duct apertures aboard ships. Meets Type H of specification Mil-1-3064. ("Shall not burn over 30 sec. *after being* exposed to a Bunsen burner for 30 sec. and flame *removed.*")	A flame and heat resistant compound for sealing duct apertures aboard ship. Meets type HF Spec. Mil-1-3064. ("*Shall not* burn at all after being exposed to Bunsen burner for 30 sec.")	A soft compound for sealing against refined oils (*medium to high* viscosity) used in transformers, etc. Type N Duxseal has equivalent oil sealing properties but is a stiffer compound.	A highly adhesive permanently plastic, odor*less white compound for* air conditioners, refrigerators, freezers and other types of cabinet construction. Also an excellent general purpose sealer where light color is needed.	Type A is extra soft and recommended for larger size extrusions or bulk (pug) purchases. It is an excellent compound for extruding on the job. Type B has a heavier consistency and is best for small (cross section) extrusions where considerable shipping and re-handling is involved. *Both are formulated for* use in automobile, truck and trailer bodies. Type B is odorless.	Has average dielectric 445 vpm; insulation resistance 10^6 megohms (per ASTM D1000-48T); and dielectric constant 3.43 (ASTM D150-45T). Highly adhesive; readily shaped or pressed in place; self welding; good for electrical splices. Maximum adhesion achieved 8 hrs. *after application.*
RECOMMENDED FOR SEALING AGAINST OR IN CONTACT WITH	Air *(Dust & Moisture)* Inert Gas Water Dilute Alkalies	Air *(Dust & Moisture)* Inert Gas Water Dilute Alkalies	Air (Dust & Moisture) Inert Gas Water High Viscosity Oil (moderate) Brine (13% NaCl)	Air (Dust & Moisture) Inert Gas Water Dilute Alkalies *(fair)*	Air (Dust & Moisture) *Inert Gas* Water (good) Dilute Alkalies (fair)	Air, Water *Inert Gas* Acid & Alkalies Brine Solutions Soaps & Detergents
COLOR	Black	Light Gray-Green	Gray-Green	White	Gray	Black
VEHICLE (BASE)	Mineral Oil	Chlorinated Fluid	Vegetable Oil	Synthetic Resin	Synthetic Resin	Synthetic Rubber
ODOR	*Slight Mineral Oil*	Very slight Musky	Slight Castor Oil	None	Type A—Slight Mineral Type B—None	Very slight Rubber
CONSISTENCY (PENETRATION) Measured by ASTM D5-52 or ASTM D-217-52T AS NOTED CONDITIONS: 5 sec; 77F; Load shown.	(50 gram load) 55-90 —	(50 gram load) 60-75 —	(50 gram load) (ASTM D-217) 90-140 —	Knife Grade (100 gram load) 65-100 Std. Gun Grade (150 gram load) (ASTM D-217) 240-300 Type S Gun-Grade (150 gram load) (ASTM D-217) 350-390	Type A (ASTM D-217) (300 gram load) 90-120 Type B (ASTM D-5) (100 gram) 65-100	(200 gram load) *60-75* —
APPROX. WEIGHT—LBS. PER GALLON	12.3	12.7	14.5	Knife 13.0 Stand. 11.8 Type S 10.6	Type A 13.5 Type B 13.1	8.9
TEMPERATURE RANGE MAXIMUM—CONTINUOUS BRIEF PERIODS MINIMUM	140F 220F —35F	140F 220F —35F	145F 190F —35F	180F 250F —35F	180F 250F —35F	160F 250F —35F
EXTRUSION CHARACTERISTICS (KNIFE GRADE) (MINIMUM SIZE)	1/8" Diam. Beads 1/16" Thick Ribbons Good; can be folded	1/4" Diam. Beads 1/8" Thick Ribbons Good; *can be folded*	1" Diam. Beads Too soft for extruding smaller sizes	1/8" Diam. Beads 1/16" Thick Ribbons Excellent; can be folded	1/8" Diam. Beads 1/16" Thick Ribbons Excellent; can be folded	1/4" Diam. Beads 1/8" Thick Ribbons Rubber type extruder required
WEATHERING AND AGING	Excellent No skin hardening	Excellent No skin hardening	Good with slight skin hardening	Excellent No skin hardening	Excellent No skin hardening	Excellent No skin hardening
ADHESION TO WOOD, GLASS, PLASTICS, METAL, RUBBER, PAINTED SURFACES	Good	Excellent	Excellent	Outstanding	Excellent	Excellent
CORROSIVE ACTION ON OR DETERIORATION OF STEEL COPPER BRASS ALUMINUM RUBBER PAINTED SURFACES WOOD	None None None None Plasticizes Stains some types None	None Slight discoloration Slight discoloration None Plasticizes None None	None None None None None None None	None None None None None None None	None None None None Plasticizes (slightly) None None	None None None None None None None
STAINING EFFECT AND AFFINITY FOR PAINT	Can be painted with most paints and enamels after priming. Stains hands but is easily washed off with soap and water.	Can be painted with most paints and enamels after priming. Won't stain hands or surfaces in contact.	Can be painted with most common paints and enamels. Won't stain hands or surfaces in contact.	Can be painted with most common paints and enamels. Won't stain hands or surfaces in contact.	Can be painted with most paints and enamels after priming. Won't stain hands or surfaces in contact.	Can be painted with most common paints and enamels. Won't stain hands or surfaces in contact.

Figure 19. JOHNS-MANVILLE Product Chart

3.7.6 Analytical Study

The efforts of the analytical study included examination of previous reports on tests of damaged bellows such as the AMETEK/Straza #8-480077, Bellows Cycling Test Report of May 24, 1968, physical evaluation as given in Preliminary Repair Technique Evaluation Test #1 and #2, and a complete comparative analysis with recommendations as given in the individual preliminary repair method evaluation sheets, all of which are included here, in the Appendix.

Based on contractual requirements of this study and the operating conditions found to exist at Launch Complex 39, the ideal field repair technique would be one which had the following characteristics:

A. No special equipment requirements.

B. No special cleaning before or after repair.

C. A minimum of operator skill needed.

D. Highly resistant to environmental conditions.

E. Highly reliable overall.

F. Very rugged (at least as rugged as prior to repair).

G. Minimum heat application.

H. Easily re-repaired and tested.

I. No equipment down-time.

None of the materials and methods is known to embody all of these characteristics based on the study, evaluation, and preliminary test accomplished in Phase I of this program. However, the Loctite sealants, which are epoxy resins and the RTV silicone rubbers come closest and appear to have good potential. It is difficult to make judgements of even a tentative nature until preliminary sealing capability tests have been accomplished.

3.7.7 Recommendations

Based on the information generated in this Phase I study it is recommended that all of the repair materials and methods which are on the preliminary evaluation sheets (and also are listed in the proposed Test Plan) be included in a family of procedures for field repairs and subjected to the testing program which is part of this report. It is recommended that where there is more than a reasonable method of applying a given material that procedures be written for each method individually and so tested. Because of the desirability of developing "no heat" methods of field repair which require little or no equipment, these types of materials and methods have been most thoroughly studied.

It is proposed in the Test Plan which follows to allow considerable latitude in the sequence of testing, continuation or termination of a given test, inclusion of new methods, test procedure changes, etc., for the purpose of insuring that no effort is spared in the search for the best possible field repair.

3.7.8 Test Plan

3.7.8.1 Scope

It is the purpose of this document to describe and propose a program of evaluation testing to be applied to candidate repair techniques which may be used on cryogenic CO_2 and vacuum jacketed lines. The tests are specifically aimed at determining the usefulness, reliability, ruggedness, permanence and practicality of repair techniques and the materials used therein. The scope of this testing program will include evaluation and documentation of all aspects of application of the repairs including:

A. Expected repair life

B. Accessibility necessary to make repair

C. Resistance to environmental conditions

D. Probable effect on reliability of system function

E. Contamination introduced by repair

F. Down-time required to make repair

G. Ability of repair to be re-repaired

H. Size of defect which can be repaired

I. Ability of repair to retain gas-tight integrity in two directions.

It is not considered within the scope of this program to determine materials compatibility or to run cost analyses of repairs and no specific provisions are included for these purposes. However, such information will be documented as it is generated incidental to other testing criteria.

3.7.8.2 Testing Philosophy

A two-stage approach is proposed for the testing program. "Stage One" will be performance of a set of basic tests on repaired small coupons. These 2 inch wide by 7 inch long, 0.015 inch thick coupons will serve as a fast, economical means of performing a large, statistically significant, number of tests on all the potentially promising repair materials. "Stage Two" will consist of a full range of environmental tests on repairs to actual bellows and/or rigid lines. The repair methods for this stage of testing will be selected on the basis of "Stage One" test results. Test results in both stages of the program will be qualitatively analyzed rather than simply placing "passed" or "failed" labels on them. The approach used in the tests and their evaluation will at all times be information gathering and exploratory in nature.

Both repair and test conditions will simulate field conditions as nearly as possible. Factors such as wind, humidity, salt spray, and accessibility will be duplicated for this program.

The size of holes to be repaired will be based on observed damage to actual flex hoses and lines used on Launch Complex 39. Damage resulting in holes of 0.010 inch in diameter or greater are common.

3.7.8.3 Test Specimens

The specimens for use in the preliminary testing phase of the program will be coupons of type 316L CRES. They will be 0.015 inch thick to allow ease and repeatability of damage application. To facilitate handling, flexure cycling, and other tests, a 2.00 inch by 7.00 inch size will be employed uniformly. Initially, as a control factor to demonstrate application on thicker walled rigid pipe, a few sample coupons of 0.125 inch thickness will be repaired and tested. These thicker specimens will be 2.00 inches by 7.00 inches size also.

The repair methods and materials which advance to the second phase of testing will employ specimens of actual bellows and pipe. The bellows will be 0.015 inch wall, single ply, three convolutions per inch, type 316L CRES to simulate actual flex hose bellows now in use on Launch Complex 39. The pipe will be 0.125 inch wall thickness, type 316L CRES to simulate rigid transfer line outer jackets in use. The pipe configuration will be two pieces joined by a lap fillet weld.

Leakage in the 2 inch by 7 inch flat coupons will be accomplished by drilling a 0.016 inch diameter hole in the specimen. The bellows specimens used in the second phase testing will be punctured using a drill or punch to produce a hole 0.016 inch in diameter. The pipe will be welded so as to leave a defect in the fillet weld to allow leakage.

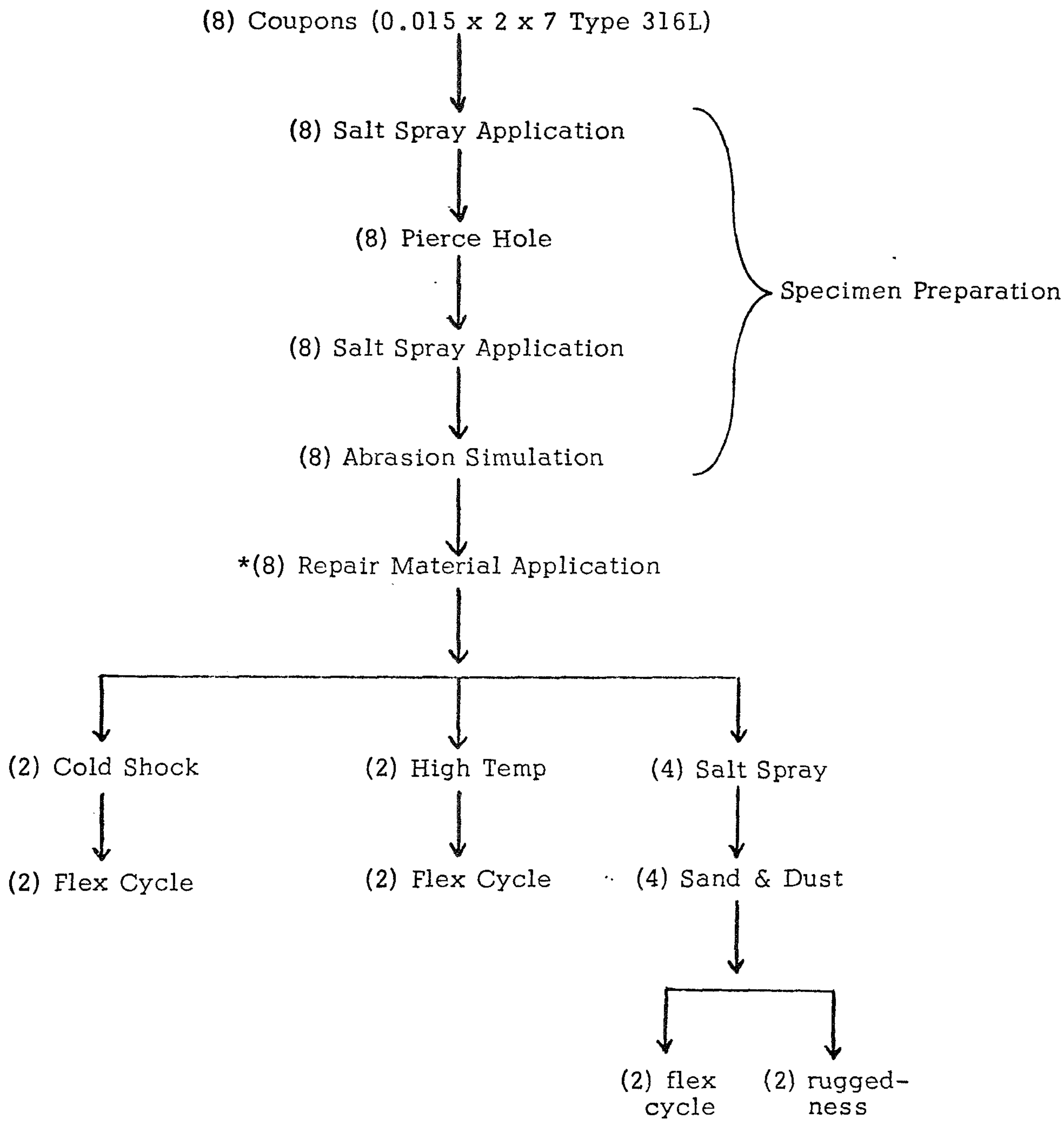
3.7.8.4 Testing Requirements

Unless otherwise specified all general requirements of KSC-STD-164D will apply to the testing herein proposed. It will be the goal of all testing to simulate actual field conditions of usage, in some cases in an accelerated manner. Separate test procedures will be written and submitted to NASA for each of the two types of testing: (a) coupon, or basic materials tests and (b) simulated repair tests.

3.7.8.4.1 Coupon Testing

The initial phase of the test program will consist of evaluation testing of all materials which through preliminary analysis have shown some merit for repair of jacketed lines. The testing will follow the sequence as shown in the Test Flow Chart on the following page. For each material there will be eight specimens of identical repair application technique. If more than one method of application is to be used for a given material, then another set of eight specimens will be prepared for that purpose. All of the eight coupons for each repair material to be tested will be treated to simulate exposure to known environmental conditions of installation at Launch Complex 39. They will be exposed to salt spray for a period and intensity designed to simulate one year of service. Then a hole will be pierced in the specimens to duplicate damage and produce leakage. After this, a shorter salt spray will be applied along with a controlled and repeatable amount of abrasion against another material to reproduce the effects of braid rubbing over bellows convolutions and hard lines being rubbed against structure. The purpose of all the foregoing preparation of the specimens will be to reproduce as nearly as possible the metal surface conditions which are known to exist on lines installed at Launch Complex 39. Once this preparation is accomplished the procedure for repair will be applied. This will be the written procedure prepared by AMETEK/Straza for each material to be tested. Where different methods of repair are to be used with the same material, alternate procedures will be generated and, as previously stated, separate sets of eight specimens will be tested. Care will be taken to assure that no deviation from procedures is allowed. Where it does become necessary to change a procedure in order to effect a repair, the AMETEK/Straza Project Engineer shall first approve such change, personally alter the written document and sign it. Each group of eight specimens will be identically repaired.

When a group of specimens is prepared and the repair material application has been accomplished, then they will be divided into three groups, (a) cold shock and flexure cycling, (b) high temperature exposure and flexure cycling, and (c) salt spray, sand and dust, flexural cycling and ruggedness testing. In group (c) above, the flexure cycling and ruggedness testing will be performed on separate groups of two each following



*After repair material application and after each test, a mass spectrometer Helium leak test will be performed.

Figure 20. Test Flow Chart

sand and dust rather than in series, since both flexure and ruggedness tests are likely to produce failure in the specimens.

At the conclusion of each individual testing operation the specimens will be leak tested on a mass spectrometer using helium as the medium. The calibration sensitivity will be 1×10^{-10} std cc/sec of He. Leakage will constitute failure and will terminate testing on individual specimens while others in the group will continue through the cycle as outlined in the Test Flow Chart.

At present the following materials are considered to be candidates for the proposed testing program. Although some may be deleted or added due to information impact later in the program, this list will serve to orient the NASA Program Manager to the scope of the program.

<u>Method A - No heat required</u>

Dow-Corning 732 RTV
G.E. RTV 102 Silicone Rubber
Loctite Sealant (various types)
Loctite Bonding Agent (various types)
J-M Volseal
J-M Albaseal
J-M Nodrseal
J-M Duxseal
Kinney Kinseal
Temp-R-Tape
Adhesive Backed Leak Foil
Dow-Corning 93-500 RTV Encapsulant
"Grip" Dental Cement

<u>Method B - Low Heat Required</u>

Dekhotinsky Cement
Indium Solder (various types)
60/40 Soft Solder
Narmco Cryogenic Cement

<u>Method C - Moderate Heat Required</u>

Silvaloy 35 Braze
Silvaloy 45 Braze

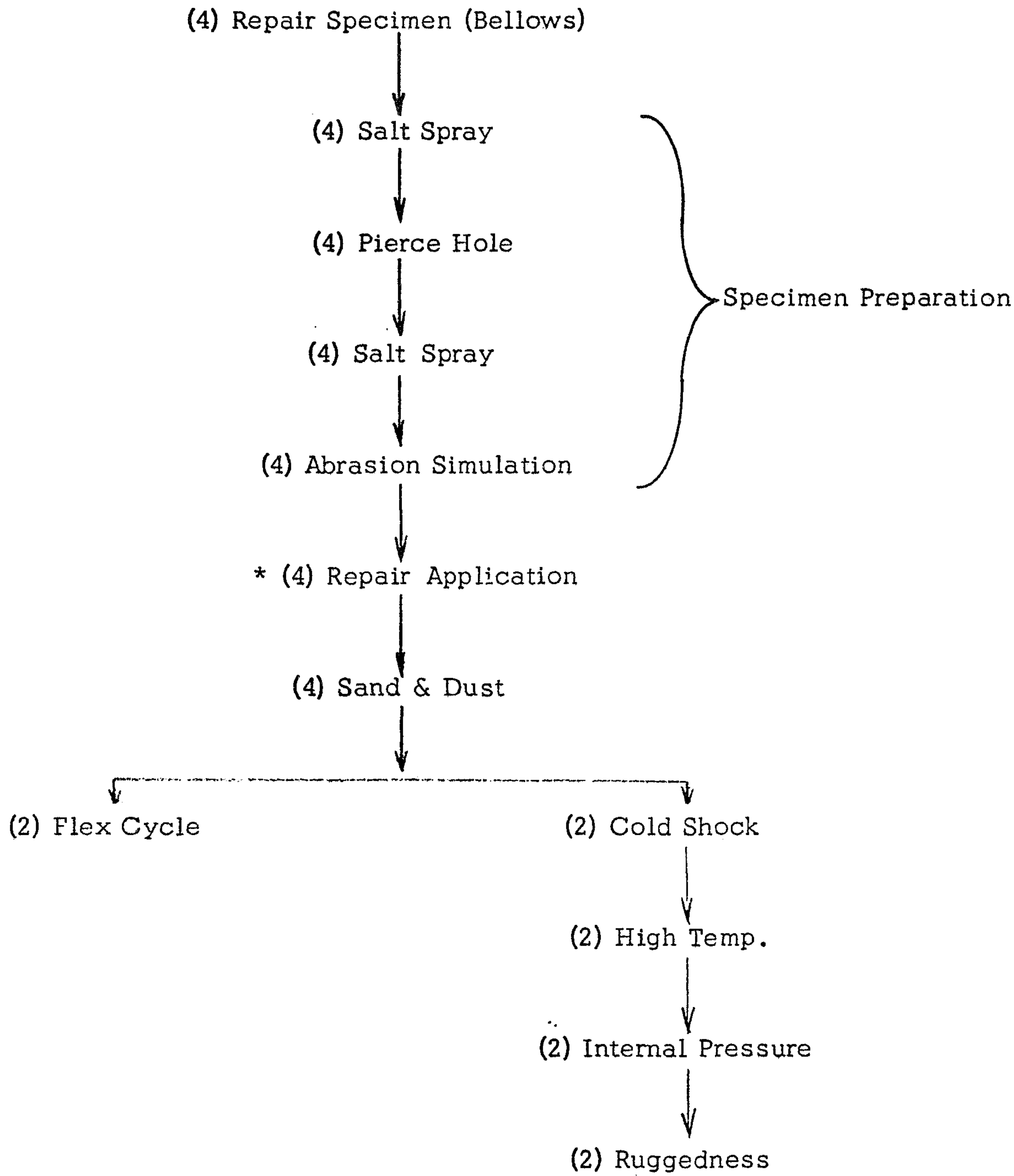
<u>Method D - High Heat Required</u>

Heliarc Welding
Plasma Arc Welding
Arc Braze

3.7.8.4.2 Simulated Repair Testing

Based on the results of the materials testing, selection of candidates will be made for further testing. This second phase of the testing program will make use of actual bellows and pipe sections for test specimens. The specimens will be fabricated and checked for leakage, then prepared for the test program by exposure to environmental aging. This artificial aging will consist of salt spray application and abrasion of the surface to be damaged against other metal. During this time a small hole will be pierced in the specimen simulating damage of the type causing leakage in known cases observed. The procedure for each repair method will determine whether surface preparation will be applied or whether the repair material will be put on without cleaning or surface treatment. The repair will be made at this point, then artificial sunlight aging will be applied to the repaired area. Ultraviolet radiation will be used to simulate this environmental condition. At this point the four specimens will be divided into two groups (see Flow Test Chart). One group of two specimens will be flexure cycled to failure with inspection stops at pre-determined intervals while the other group will be subjected to cryogenic cold shock, high temperature exposure, a second ultraviolet radiation interval and a final ruggedness test. This second group will be subjected to the tests described in the order mentioned in series. The cryogenic cold shock will consist of immersion of the entire specimen in LN_2 at -320°F followed by several (five to ten) cycles of flexure when the specimen is back to room temperature, then a helium leak check. The high temperature test will be similar except instead of an LN_2 bath, a flame spray nozzle with a 1200°F temperature will provide thermal shock for a short period (five to ten seconds). Following the second untraviolet exposure the two specimens will be subjected to a ruggedness test for the purpose of determining the repair methods' resistance to shock and abrasion. The test machine depicted on AMETEK/Straza Drawing 8-050075 will be used to apply a predetermined degree of impact sufficient to cause a 1/8 inch indentation in the specimen when struck at a 90° angle to the axial centerline of the test article.

Criteria for judging the effects of various tests on specimens will be visually detectable deterioration and leakage of helium through the specimen. These types of inspection will be done after each increment of testing on each specimen. In the case of salt spray, sand and dust, cold shock, high temperature and ultraviolet tests, the visual inspection and leak check will be made at conclusion of each test only. In the case of ruggedness (impact) testing, inspection will be made after each blow is



*After repair material application and after each test a mass spectrometer He leak test will be performed.

Figure 21. Test Flow Chart

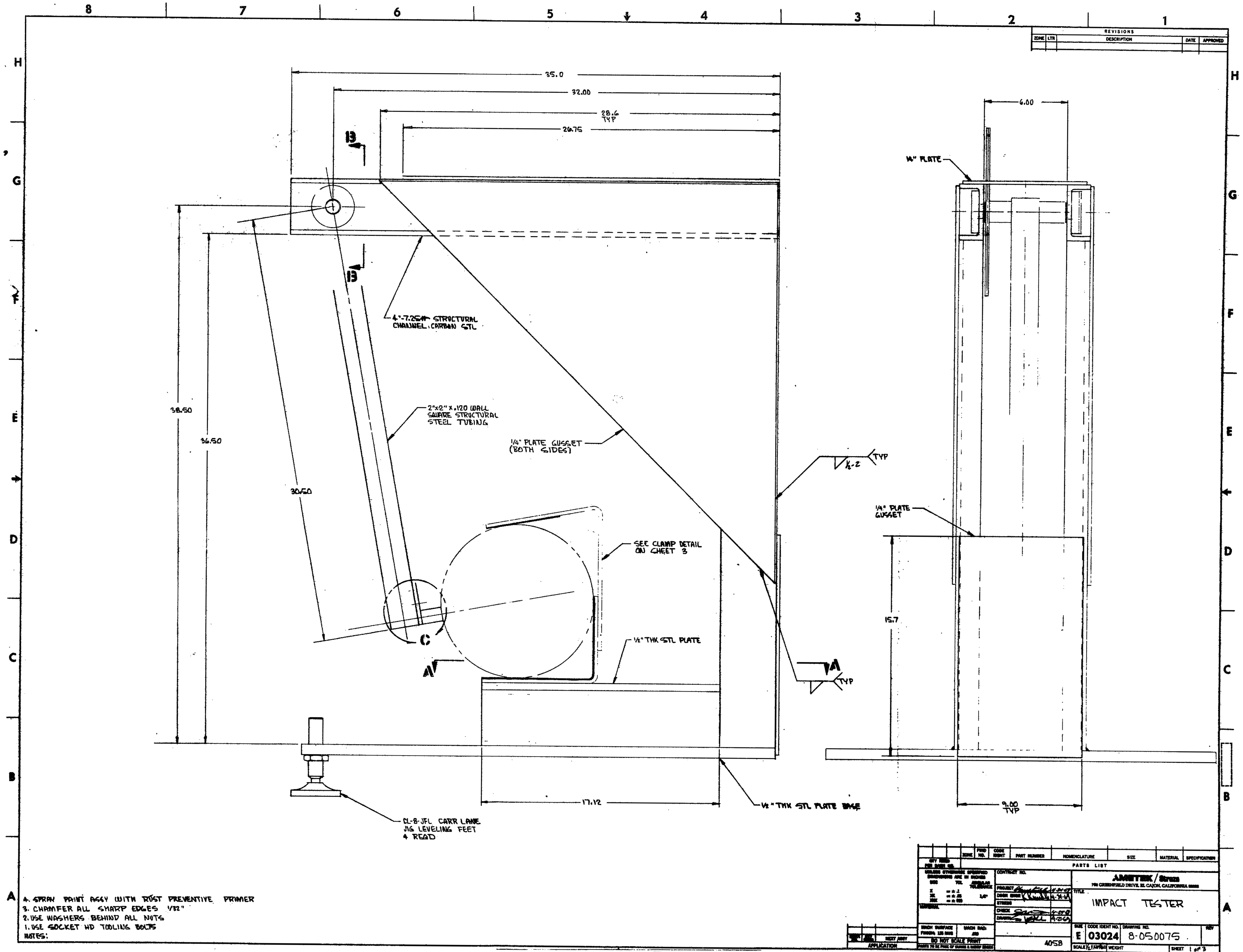


Figure 22. Impact Tester

struck and in the case of flexure cycling after a pre-determined number of cycles depending on the induced stress level.

All repair methods and/or materials will be attempted on bellows test specimens. There may be instances where a method or material will not successfully repair a leak in a bellows due to inaccessibility or lack of flexure strength. In such cases, the method or material may be used and tested on a rigid pipe specimen if it is otherwise promising. Generally it is assumed that a material or method which is suitable for a bellows leak repair will also be successful on pipe, but this assumption will be verified in doubtful cases.

3.7.8.5 Documentation

A test log shall be kept by the Test Engineer, listing the following minimum information:

A. Date of test and test item identification.

B. Names of testing personnel and others present to observe the test.

C. A brief description of the test set-up.

D. Test results, damage, condition of the test item as compared to the condition prior to test.

E. Any circumstances or conditions which might affect the test results in any way.

In addition, a test data sheet will be kept on each individual test and the foregoing information recorded.

Both the Test Engineer and Project Engineer will sign the test log and entries after test.

Photographic evidence shall be made of the test item after each environmental test and at any time during the test sequence when circumstances deem it appropriate. Photographs shall be identified with date, type of test, test item identification and any unusual conditions present.

A test report which will include all of the foregoing information will be generated by the Project Engineer. This report will include all facts and conclusions, obvious and otherwise, which the test generated.

3.7.9 Appendix

The following material, referred to in this report, is given here in order that continuity could be maintained in the main body of the text. It should, however, be understood that these articles are pertinent to the context in which they are referenced.

Item	Title
1	"Leak Testing Cryogenic Vessels"
2	"Bellows Cycling Test Report"
3	"Preliminary Repair Technique Evaluation Test 1"
4	"Preliminary Repair Technique Evaluation Test 2"

LEAK TESTING CRYOGENIC VESSELS

The following is a condensation of an article by Robert J. Roehrs, Chief Engineer and Manager of Quality Control at Killebrew Engineering Company, St. Louis, Missouri.

Leak Testing Defined

It is important that in-leakage of gases into the insulation, or jacket space, be held to a minimum. To insure that both the inner vessel and the outer jacket are "tight" enough to maintain the proper vacuum over prolonged periods of time, even the smallest leaks may need to be eliminated. Leak testing is concerned with the determination of the rate at which a liquid or gas will penetrate from anywhere within a "tight" component or assembly to without, or vice versa, as a result of a pressure differential between the two regions.

Nothing is "leak tight" except as compared to a standard or specification and even then only at the time of test. The task of finding small leaks in a high-vacuum system is tedious and time consuming. There are methods for facilitating the detection and location of leaks in a pressure or vacuum vessel. However, most are used when considering larger leaks that can be tolerated in the vacuum system of a cryogenic container. A device for indicating changes in pressure or changes in the nature of the vapor mixture must be very sensitive to find small leaks in cryogenic containers having many leaks or in containers having surfaces which outgas.

To insure that in-leakage into the medium to high-vacuum area does not exceed the maximum allowable, the "leak tightness" evaluation of the annular jacket space of a cryogenic vessel is several orders of magnitude more difficult that the evaluation of equipment fabricated for use in full (low) vacuum service. For vessels designed for full-vacuum applications such as freeze drying, the testing is accomplished by first pulling a vacuum of 28 or 29 in. of Hg (1 to 2 in. of Hg, absolute). The evacuation valve is closed and a manometer or a standard vacuum gage is checked for any appreciable pressure increase.

But this method of evaluating the tightness of a vacuum system has been found impractical for cryogenic containers. Consider a typical case: If a jacket volume of 1000 cu ft is assumed, and the space is to be evacuated to an absolute pressure of 1×10^{-2} torr, and if the total allowable integrated leak rate into this space is not to exceed 1×10^{-4} atm cc/sec, this test is not extremely difficult to perform with a helium mass spectrometer leak detector. However, if the leak rate is to be determined by the rate of rise method (pull a given vacuum and watch the rate of pressure increase in a specific period of time) it would be highly impractical to perform due to the sensitivity of standard vacuum gages. Actually, the leak rate, when applied to the system, converts to a rate of pressure rise of 9×10^{-6} torr (0.009 microns Hg) per hour or in other words, it would take approximately 1000 hr for the system pressure to change by 9 microns of Hg.

The field of leak testing is cluttered with differing nomenclature and many sets of units. The significant term involved is leakage, or mass flow rate. It has the dimensions of pressure times volume divided by time. We have selected the units of atmospheric cubic centimeters per second (atm cc/sec). Note this is not a volumetric flow. The volumetric flow past a point carries the units of volume divided by time or cc/sec.

Another point of nomenclature confusion has to do with the words "leak" and "leakage". It is important to recognize that when a fluid flows through a small hole, the rate of flow depends upon both the geometry of the hole and the prevailing fluid conditions of pressure, temperature and type of leak. The word leak generally refers to the physical hole that exists and is independent of the quantity of fluid flowing, while the word leakage refers to the actual flow or leak rate indepent of the physical size of the hole. In this sense, the phrase "minimum detectable leak" refers to the smallest physical size hole which can be detected, while "minimum detectable leakage" refers to the smallest fluid flow rate that can be detected.

Hunting Leaks

Of the various methods for hunting leaks in a cryogenic vacuum system, one method has many advantages. It involves directing a stream of relatively inert tracer gas at the suspected joints of the container while looking for changes in the concentration or the presence of this particular gas in the annular space under evaluation. Advantages are: (1) The tracer gas will not contaminate the vessel or the pumps; (2) it will enter the annular space readily through small leaks; (3) there is little danger of closing a leak and having it open some time later and (4) once a leak is found, there is no time lost in continuing the hunt because the tracer gas entering the system is quickly pumped out. The ideal "leak detector" is an instrument which continually samples the gas in the system and instantaneously notes the presence or change in concentration of the tracer gas regardless of the presence of other gases or vapors.

A testing method which has been successful in large vacuum equipment combines improved vacuum techniques and a helium mass spectrometer leak detector. This equipment can detect the presence of less than one part of helium in 10,000,000 parts of air. The ultimate sensitivity of such devices is usually quoted on the basis of 100% tracer gas concentration in the system or, equivalently, on the amount of tracer leaking. In a practical situation this concentration is necessarily kept down for reasons of safety and economy. With 1% tracer, of course, the sensitivity figure must be correspondingly altered.

The helium leak detector is a portable mass spectrometer which is especially designed to be highly sensitive to helium gas. A mass spectrometer is an instrument for separating or sorting atoms of different mass. Gas molecules entering the mass spectrometer are bombarded by electrons emitted by a heated filament. The ion beam produced is accelerated in the form of a narrow beam by means of an electric field. Ions then pass between the pole pieces of a permanent magnet where the magnetic field deflects the ions in circular paths. The radius of curvature of a path depends upon the mass of the ion; therefore, ions having equal mass will all emerge from the magnetic field at a certain position. A helium leak detector is adjusted so that only helium ions are collected. The flow of helium ions to the collector constitutes a minute electrical current which can be detected, amplified and used to activate an electrical meter and to control the pitch of an audio signal generator.

Preliminary tests

Prior to employing an extremely sensitive testing method, it has proven expedient to perform a preliminary test, such as an air and bubble test or a halogen test using the alkali ion emission type detector. Large leaks can be the most difficult and exasperating ones to find. Most of the sensitive techniques and equipment developed for leak testing vacuum systems are inapplicable at the pressure attainable when these large leaks are present. Consequently, large leaks usually are sought by one or another of a number of relatively crude techniques, most of which are based on pressure testing methods.

In the bubble method, a solution may be spread over the entire surface of the suspect areas so that bubbles will be produced as the escaping gas attempts to pass through the solution. Several precautions should be taken to obtain the best results. When testing flanges, threads or other joints which have a large exposure area, it is necessary that the bubble solution bridge the entire joint. Air will invariably leak out through the smallest pinhole which is not covered. A second caution is the choice of a bubble solution. For high sensitivity, the film must not break away from the joint and the bubble formed should not break rapidly due to air-drying or low surface tension. Another requirement is that there be a minimum of bubbles in the solution so as to reduce the problem of trying to discriminate between solution bubbles and those caused by leakage.

Several types of instruments might fall into the general category of halogen testing. They include the halide torch, thermal conductivity detectors and the alkaline ion emission detector. The minimum detectable leakage of these test methods varies by several orders of magnitude. For the preliminary evaluation of cryogenic containers, the ion emission type is popular. The ultimate sensitivity of this detector is claimed to be 1 X 10^{-9} atm cc/sec but in actual application the limitations of the technique reduce this to a much lower value.

The detector (sensing element) operates on a principle of ion emission from a hot plate to a collector. Positive ion emission increases with an increase in the amount of halogen compound gases present. This ion current is amplified to give an electrical signal which indicates leakage. Unlike electrons, which are simply basic units of negative electricity, ions are positively charged particles of some specific substance. In general, emission of ions means a loss of material from the cathode emitting them. One unique feature of ion emission, however, is that it can be made to occur frequently in the air.

When conducting the halogen test, the annular space is usually pressurized to a few psi with 10 to 20% tracer gas and an attempt is made to detect the leak by "sniffing" the exterior of the jacket with the instrument's probe. The probing begins at the top of the system and continues downward because halogens are heavier than air and if probing were to progress upward, false indications could be observed at the lower elevations due to halogens that had settled from leaks in the upper portions of the system.

There are several different pressure-type alkali ion emission halogen leak detectors. Each includes a control unit and a probe through which air is drawn at about 1 cu ft/hr or 30 cu in./min. When searching for leaks, the probe tip is moved over joints and seams suspected of leaking and certain precautions are necessary in this exploration. Too rapid a search may miss the very small leak. If this risk is to be avoided, the speed at which the probe is moved must be in proportion to the in-leakage tolerance. In testing these joints and seams for an allowable leakage on the order of 1 X 10^{-4} atm cc/sec, the probe travel can be 1 to 2 in./sec; but the probe speed should be reduced to 1/2 in. per sec when looking for lesser leakage.

The probe tip should lightly touch the surface as it is moved. Where forced ventilation is required to keep the air free of halogen vapors, it must be stopped during the actual testing or care should be exercised to be certain that drafts do not blow the leaking gas away from the detector probe. When the probe passes over or close to a leak, the tracer gas is drawn into the probe with the air and through the sensitive element where it is detected. The indication of leakage is either audible or visual.

The practical sensitivity of the preliminary air and bubble formation test ranges from 1 X 10^{-2} to 1 X 10^{-4} atm cc/sec; whereas, the halogen test allows for the detection of leaks on the order of 1 X 10^{-5} to 1 X 10^{-6} atm cc/sec. It should be noted that during the preliminary tests, each of these methods is used only for the determination of point source leaks. Theoretically, a number of passages that allow individual leakage rates less than the minimum detectable limits of the particular method may exceed the specification when added together.

At this point it should be stated that any gas tracer system, no matter how sensitive, which responds to the simple absolute level of concentration, will soon become incapable of detecting leaks when the ambient tracer concentration rises to the level capable of giving spurious signals. This is the major disadvantage of the halogen leak detector.

After a preliminary test is performed to locate gross leaks, it is usually desirable to perform a mass spectrometer probe test. The probe may be a hypodermic needle or a similar orifice valve to minimize the area subjected to helium. To do so, the vacuum pumping station is connected to the annular jacket space of the cryogenic vessel. The mass spectrometer must be thought of as a "sampling system", not as a "pumping system"; therefore, it is necessary to provide a pumping station for evacuating the system to be tested. The size of the pumping station depends upon the volume to be evacuated, the length and diameter of the pumping lines, and the ultimate pressures to be obtained. In general, the jacket space is evacuated to a test pressure of 1×10^{-4} to 1×10^{-5} torr by utilizing an oil diffusion pump that is backed by one or more high-capacity mechanical pumps. The mass spectrometer sample inlet line is connected between the diffusion pump and the mechanical pump(s) to utilize the high pumping speed of the diffusion pump at low pressures. Special consideration should be given to the connection of the pump station to the vessel since poorly designed test connections can be a major source of difficulty in leak testing. Common sources of trouble are leakage and excessive helium contamination. To avoid these time wasting difficulties, the following points should be observed:

1. Avoid excessive amounts of rubber, especially rubber tubing, because it can absorb helium. Thus, when a large leak is encountered, appreciable quantities of absorbed helium may be difficult to remove by pumping. The "contaminated" rubber may then give false indications on succeeding tests. Some rubber may be necessary to make vacuum connections; however, its use should be kept to an absolute minimum. Not only is rubber tubing subject to helium contamination, but it eventually becomes contaminated with other materials which prevent the attainment of the vacuum required for good leak testing.

2. When applied to gaskets in moderation, a good low vapor pressure vacuum grease, such as Apiezon, Lubriseal or Silicon, will be of considerable aid in making a vacuum-tight joint. Like rubber, however, excessive use of vacuum

grease will cause helium contamination; furthermore, large quantities of grease will act as a dirt catcher and the system will soon be so dirty that a good vacuum will be unattainable. Only a light film of grease need be applied to the gaskets, and the excess should be wiped off. A rule of thumb would be to apply an amount of grease equivalent to that obtained when removing body oil from the nose of ones face.

3. Commercially-available molded rubber "O" rings have a circular cross-section that make very reliable and convenient vacuum seals. About 3/4 of the "O" ring cross-section is recessed in a groove and the balance is compressed into the groove upon attachment of the covers. For vacuum applications the use of flat gaskets should be avoided whenever it is possible to use "O" rings. However, when it is found necessary to use flat gaskets, their sections should be held to a minimum so that the vacuum system "sees" the smallest possible amount of rubber.

After the mass spectrometer is connected to the diffusion pump foreline, the diffusion pump begins to pump on the annular space after the 1×10^{-1} torr pressure region is attained. The diffusion pump makes possible the production of much lower system pressures, assures molecular flow within the system, allows reasonable probe speeds and provides rapid response and minimum difficulty in locating tests.

For fast, accurate leak testing with the mass spectrometer, two requirements are of the utmost importance: first, the system should react as rapidly as possible when a leak is "probed". That is it should have a short response time. Second, when the tracer gas is removed from the actual area where the leak is located, the leakage indication should fall to zero in the shortest possible time. That is, it should have a short "clean-up time".

If these requirements are not met, the leak testing process is delayed to a large and sometimes intolerable extent. To illustrate, picture a section of weld being probed at a constant rate. If the response time is poor, the leakage indication will appear sometime after the probe has moved on well beyond the leak, and the probe will then have to be backtracked slowly until a second signal is obtained. But, this second signal cannot be observed distinctly until the first signal has been removed, or cleaned-up. Therefore, the clean-up may be of equal importance to the response time.

Response and clean-up times are characteristics of the test system as a whole, including the annular space, the evacuation lines and the auxiliary pump. They are not merely functions of the leak detector alone. The leak detector responds almost immediately to any change in helium concentration that occurs at the throttle valve. In a test system, the delay in response is due to the time necessary for the helium concentration to build up at the throttle valve. The delay in clean-up is due to the time necessary for the pump to remove the helium from within the volume of the system. An annular jacket space, having a large volume will cause long delays, whereas a high speed pump will assist in reducing these delays.

If one were to pump the annular space directly into the leak detector, the time response would be determined by the pumping speed of the instrument itself, which is about 5 liters/sec with the throttle valve wide open. Therefore, reasonable time response would result only with volumes up to several liters. However, even on large systems where time is a secondary factor, this method yields maximum sensitivity, since there is no external pump to "rob" the helium.

Attached to the foreline of the diffusion pump, the mass spectrometer is turned on, allowed to stabilize and a small jet of helium probes the suspect areas. However, before performing the test, the ion accelerating voltage should be set at the helium peak, the filament is turned on, and the throttle valve is open. It is also advisable never to valve off the auxiliary pumps unless the pressure is sufficiently reduced to allow the leak detector throttle valve to be wide open. Whenever any change or adjustment is to be made to the test system, be sure to close the throttle valve. This will prevent accidental admission of air to the leak detector. The throttle valve should never be opened unless the auxiliary pump valve is first opened. Last, but not least, turn the filament switch off when testing is suspended for ten minutes or more.

Probing for the Leak

Probing for a leak in the jacket should proceed from the upper side of the vessel to the lower. In this way the helium, which rises, will flow back only over areas already tested. When testing individual joints, save time by using a generous flow of helium continuously from a flexible rubber tubing (1/4 in. diameter). If an indication is noted on the milliameter of the mass spectrometer, it is necessary to isolate the leak. Its exact location may be determined by means of a finer jet of helium emitted from a probe. Using a fine jet, the operator can limit narrowly the area covered by helium. In other words, a large helium flow may be used to check a large area of the vessel, or a small spray of helium may be used to check only the suspected area of leakage. The only leaks that will be found, of course, will be those that have been subjected to the helium spray. It is, however, a very useful method for quickly pinpointing the location of leaks.

Don't be fooled into thinking the leak always exists at the spot where the probe is held; the meter deflection may be due to a very large leak located some distance away. To prevent this, the leak should be located and either repaired or temporarily sealed. When a point appears to leak, but does not give a consistent response on the detector, suspect a large leak in some other location. The varying leak indication is due to erratic puffs of helium being blown to the large leak. In locating the leak, the detector out-put will be at a maximum when the probe is directly over the leak. When two possible points of leakage are close to one another, it is sometimes difficult to determine which of them is responsible for the leak indication. It may then be necessary to mask off one of them (with tape) to exclude its possible influence. Using a fine probe and a minimum flow of helium will also help.

Quantifying Leakage Rate

To measure accurately any existing leakage, it is necessary to place a known standard leak approximately 1×10^{-7} atm cc/sec somewhere on the system under test. A shut-off valve should also be provided to isolate the standard before and after calibration. These standards are small sealed containers of atmospheric-pressure helium with a very small leak built into them. Some units are made of glass, others of metal. Commercially-available glass units depend on the slow diffusion of helium through a quartz membrane to achieve a constant, very small leak rate. The accuracy of the standard leak is claimed to be within ±10% of the value shown on the calibration label. Helium flow from the container is so small that the leak standard can be connected to a 1×10^{-3} torr evacuation system for many hundreds of hours before the helium pressure in the container goes down appreciably.

The standard leak can be used to determine the sensitivity of a leak detector as well as the system of which it is part. With a known leak that can be introduced when desired, one can determine the difference between the mass spectrometer output due to the known standard leak and the mass spectrometer output due to overall helium in-leakage. The leak detector is calibrated in terms of leak rate per scale division on the meter, by simply noting the change in meter reading caused by the known calibrated standard leak. The meter reading caused by an unknown leak is converted to a leak rate by simple proportion.

Detector sensitivity can be established by using a standard leak that is connected to the leak detector inlet directly, or to an inlet manifold which does not leak. After the mass spectrometer has run until the scale reading is constant at the specified source pressure indication, the sensitivity can be calculated. The scale is read in divisions.

This calculation may be better explained by the following example: Assume the leak detector scale reads 2200 divisions at 0.2 microns Hg source pressure under equilibrium conditions and the standard leak has a flow-rate of 6.47×10^{-7} atm cc/sec. The smallest readable output is 5 divisions. The detector sensitivity is $6.47 \times 10^{-7}/2200 = 2.94 \times 10^{-10}$ atm cc/sec/div. Since the smallest readable output is five times this value ($2.94 \times 10^{-10} \times 5 = 1.47 \times 10^{-9}$ atm cc/sec), the smallest leak that will give a readable output when the source pressure reads 0.2 microns Hg with no areas leaking in, will be 1.47 X 10^{-9} atm cc/sec.

For calibration of the vacuum system, the standard leak and associated gages are placed in the representative region of the system that is farthest removed from the leak detector so that a true value of the minimum detectable leak for that system can be obtained. In other words, it is preferable to have the standard leak located as far as possible from the pumping port.

If a leak is discovered, it is essential to know if it occurs in the inner vessel or in the outer vessel. Therefore, the inner vessel test is performed prior to surrounding the outer vessel with helium and any output on the mass spectrometer will be indicative of leakage into the inner vessel. Then, with helium remaining in the inner vessel, the outer shell is flooded with helium and the mass spectrometer output will be due to the total integrated in-leakage into the annular jacket space. The helium concentration in the inner vessel and in the "bag" is important, since the actual leak rate is proportional to the percentage of helium used in the test. In other words, it is a straight line function. For example, if the measured leak rate is determined to be 1 X 10^{-6} atm cc/sec helium with a 20% concentration, then the actual leak rate is 5 X 10^{-6} atm cc/sec helium.

After the vessel annular space has been evacuated, outgassed and leak tested, it is obviously desirable to prevent re-outgassing each time it is re-evacuated. One way of minimizing this effect is to backfill the space with an extremely dry gas when bringing it up from vacuum to atmospheric pressure prior to opening to atmosphere.

Welding Considerations

Joints for the high-vacuum jacket space are far more critical than corresponding pressure vessel joints that also operate under one atmosphere differential pressure. Microporosity of the weld, entrapped gases, or solids that outgas become major problems in the high-vacuum area.

Fundamentally, vacuum systems are designed to withstand one atmosphere external pressure. Although safety requirements can be readily specified from the ASME Boiler and Pressure Vessel Code, when designing high-vacuum equipment one must also consider other requirements. Extremely small defects or inclusions in welded joints may be undetectable by the usual nondestructive testing methods, but because of such leaks and gas sources, the performance of the vacuum portion of the cryogenic vessel may be seriously compromised.

Effective welded joints avoid trapped volumes or faying surfaces exposed to the vacuum side of the joint, both of which may hold foreign matter which outgas during evacuation. Since cleaning such crevices is often impossible, joint design and welding processes must eliminate these traps. Welding should be performed from the vacuum side of the joint whenever practical. The under bead often contains unavoidable microporosity that is too small to affect most properties of the structure. If exposed to vacuum, these voids often act as a trapped volume. Leakage from this source may be avoided by at least welding the seal pass from the vacuum side.

Virtual Leaks

In addition to the obvious sources of gas inside a vacuum system, more insidious sources exist which are called "virtual leaks". They are the result of water vapor and gas absorbed on or in the surface and pores of all material in the system exposed to atmospheric pressure prior to evacuation. When attempting to pump down a system, it is quite startling to find the quantity of such gases that must be evacuated. Many materials absorb both permanent gases and condensable vapors when exposed to the atmosphere, and then slowly release these gases and vapors when the system is evacuated. In addition, the presence of any oxides, dirt or grease within the system greatly increases the amount of outgassing which may be expected. As a result, the pumpdown time may be longer by a factor of 10 or even 100 than the theoretical pumpdown time for the volume of the jacket involved.

Personnel Requirements

The best equipment that can be devised and assembled for leak testing is useless without proper personnel. Training, though extremely necessary, cannot take the place of the type of intelligence and thinking that is often referred to as ingenuity, resourcefulness, clear thinking, or imagination.

The primary requirement for personnel is the innate ability of the man. Complete theoretical training is necessary, but wasted insofar as actual testing is concerned, if the man does not have adequate ability. In addition to technical abilities and training, the good technician must have other attributes. He must be determined to do a conscientious job under any circumstance. He must be willing to listen and to cooperate with the many types of men encountered in the field, but he must not compromise the quality of his work for the convenience of himself, his group or some one else. As a company representative he must be an ambassador of good will for his organization, yet be efficient and get the job done properly in a minimum time.

Final Evacuation

After the in-leakage into the annular jacket space has been determined to be less than the allowable leak rate, which is normally 1×10^{-4} to 1×10^{-6} atm cc/sec, the space is filled with perlite and the evacuation process is begun. Evacuation can be a difficult problem, since perlite is a porous, absorbing material. A gas molecule can be evaporated and absorbed many times during the evacuation process before it is finally removed from the bulk material. Thus, if evacuation is to be accomplished in a minimum amount of time, the powder must be kept dry during the filling operation because moisture content is the greatest impediment to proper evacuation. Evacuation may require several weeks (if it can be accomplished at all) when a large volume of wet perlite is used.

It is also imperative that all detrimental in-leakage into the annular space be determined prior to the addition of perlite insulation because helium not only absorbs on the surface of the perlite particles but also diffuses into the structure. In fact, the presence of helium in the powder makes leak testing by use of a helium detector very difficult if not impossible.

BELLOWS CYCLING TEST REPORT

1.0 PURPOSE OF TESTS

There has been insufficient test data results available from discontinuities in thin wall metallic bellows to allow the establishment of realistic stress concentration factors. There has also been a lack of comparative data on the varying locations of such discontinuities. For this reason, a mechanical test program was initiated that would provide to some degree such information for future bellows design and evaluation.

2.0 SUMMARY

The most conclusive method of establishing comparative stress level data on thin metallic bellows is in simulated work cycling to failure. It is also well established that bellows design parameters vary according to wall thickness, convolution height/pitch ratio, and diameter. For this reason, a bellows design was chosen for the test that would be relatively representative of the type of configuration used in quantity by Straza Industries and for the entire range of mid-sizes and gauges. This "mid-range" could arbitrarily be considered as sizes from 2 inch to 18 inch diameters and .008 to .031 inch wall thickness. The pitch/span ratio used was representative of the range from 1/1 to 1/2, encompassing the greatest majority of bellows made by hydraulic or roll forming methods for aerospace.

The basic reason for investigating the subject of discontinuities in bellows was to provide some method of gauging the feasibility of making welded repairs on bellows. The extremely high cost of some of the individual bellows units used in aerospace has made it necessary to seriously consider adopting standard repairs for defective bellows. Actual repairs were therefore made in the test bellows to simulate typical practical repairs. Since a bellows convolution configuration is divided into three sections, i.e. crest, side walls and root, the repairs were made in a manner to furnish comparative data on these three areas. One further area was also considered, that of the end skirt of a bellows, where occasionally repairs have been necessitated due to imperfect methods of attachment.

With typical weld repairs made in the aforementioned positions, four test bellows were cycled to destruction and data gathered on the modes of failure. Although normal cycle life had been calculated for these bellows based on the motion input to which they were subjected, parent material failures did occur which even more satisfactorily established comparative values for concentration of stresses in the discontinuity areas. While limited by the number of samples available for testing, the consistency of the data was encouraging and resulted in a clearer understanding of repair problems.

Utilizing existing production tooling, four bellows were fabricated for the program with the following dimensions: (Ref. BDSK-217 attached)

Bellows I. D.	9.980
Bellows O. D.	10.75

Material	(1) ply .010 Type 316 CRES
Pitch	.30 inch
Number of Convolutions	5

3.0 DESCRIPTION OF TESTS

3.1 Spring Rate Test

Utilizing standard spring rating techniques for bellows, each bellows was set up and tested in compression, using Dillon direct reading force gauge. (See Paragraph 4.1 for readings.) The spring rates were taken a) to determine consistency of the bellows, one to the other; and b) to confirm analytical figures and to aid in determining stress levels for the movements to be used for fatigue testing.

3.2 Mechanical Cycling Test

The machine used was a hydraulically actuated bellows cycling machine capable of being set for any required axial stroke length. Pure axial cycling was used as being the most consistent and predictable type of fatigue testing that can be performed. Rate used was 60 cycles per minute. The bellows were equipped with end bands and end cover plates (refer to attached BDSK-217), and positioned vertically in the machine. To check failure, the inside of the bellows cavity was filled with dye penetrant while the outer surface of the bellows was dusted with developer. One hundred percent visual surveillance was kept of the bellows during cycling so that all failures could be detected immediately. Time lapse between failure and detection was estimated as three seconds or three cycles at which time the machine was stopped and the record made of failure, location, the cycle count at failure and any other pertinent data. The cycle testing was then continued until such a time as excessive bleeding of the dye precluded detection of any more failures. In this way each bellows was capable of producing several failures as shown by the results in Paragraph 5.0.

The use of dye penetrant was chosen as the means of failure detection for two reasons. Per the preceding paragraph, the use of this media made it possible for more than one failure to be detected from each bellows unit. The second reason was that Straza utilizes a great many bellows in vacuum jacketed line work and it was desirable to obtain data on unpressurized bellows. It is recognized that results of tests conducted upon pressurized bellows could vary considerably from those shown in this report, particularly in the side wall repair failure history. The positive results of these tests indicate that such pressurized tests should be conducted at a later date.

Axial movement for the bellows cycling was calculated in order to give a predicted cycle life of 5000 cycles. It was considered that this was sufficiently lengthly to give an acceptable scatter pattern on failure figures, yet short enough to fall within the budget allowance for the tests. Axial motion was 3/8 inch compression and 3/16 inch extension.

4.0 TEST RESULTS

4.1 Spring Rate

Each bellows was subjected to axial deflections of 1/16 inch, 1/8 inch and 1/4 inch. The forces in pounds required to deflect each bellows these amounts was multiplied by the proper factor to obtain the pound per inch spring rate. As characteristic of all bellows of this type, it will be noted that the spring rate appeared to decrease as the deflection movement increased. This is the natural result of the new or uncycled bellows taking permanent set.

Bellows S/N	Deflections 1/16"	1/8"	1/4"
#1	1088 lbs/in.	968 lbs/in.	740 lbs/in.
#2	1152 lbs/in.	1000 lbs/in.	760 lbs/in.
#3	1200 lbs/in.	1040 lbs/in.	724 lbs/in.
#4	1088 lbs/in.	1024 lbs/in.	768 lbs/in.

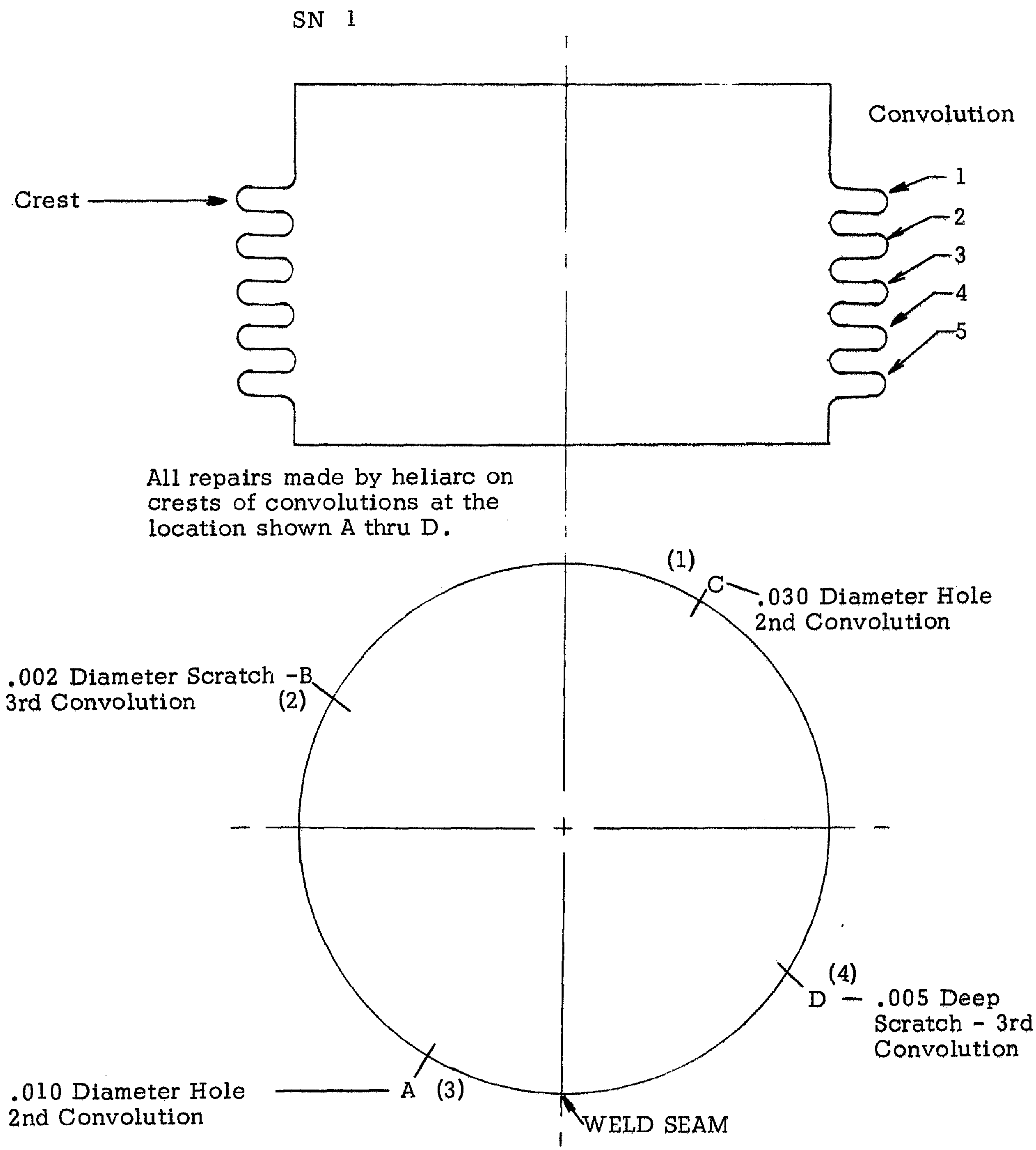
For the convolution height, pitch and number of convolutions, the bellows showed good consistency.

4.2 Mechanical Cycling

The results of the mechanical cycling testing is shown on the accompanying data sheets. It will be noted that parent material failures took place within the range of 3505 to 6180 cycles. This was an un-anticipated spread. Evaluation of the various parts, however, made it apparent that the earlier parent material failures on S/N 4 were the probable result of locally deformed convolutions. This deformation was present on this bellows due to spreading of convolutions to allow access of the welder to the locations where the simulated weld repairs were made. End plates were already installed on the sample when the repairs were made and there was no access to the inside of the part. Where access is allowed, the convolutions are normally re-rolled or re-spaced to their original configuration after the repair is made. However on this sample such replacing was not possible. While this deformed condition probably resulted in undesirably early failures in the part, it is somewhat representative of actual conditions that could be encountered in field repairing.

On the remaining samples, the repairs were made before the end plates were welded on, so in those cases where reshaping of the convolutions was required to re-establish original configuration, this was done. For that reason, S/N's 1, 2 and 3 afford a more representative delta test condition between parent material and discontinuities.

All repairs were made with T.I.G. process and adding filler rod. Standard weld repair techniques were used, argon gas back up being used in all cases. Each repair was inspected visually, dye checked, and then adjudged by the cognizant test engineer and quality control as typical and a good example of such repairs.

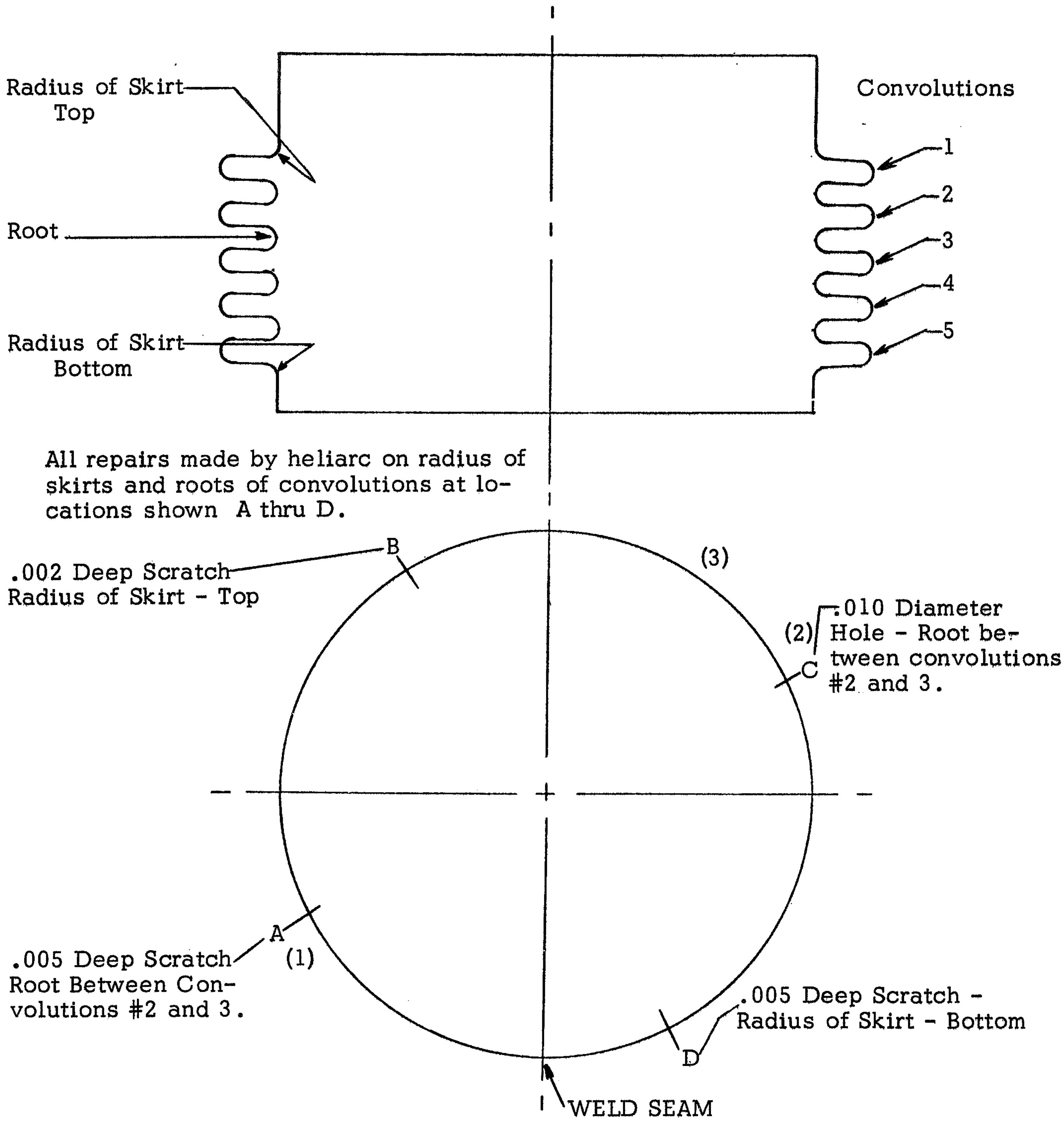


<u>FAILURE</u>

1. Weld Repair C - 819 cycles.
2. Weld Repair B - 819 cycles.
3. Weld Repair A - 821 cycles.
4. Weld Repair D - 856 cycles.

Figure 23. Heliarc Repair on Crest of Convolution

SN 2

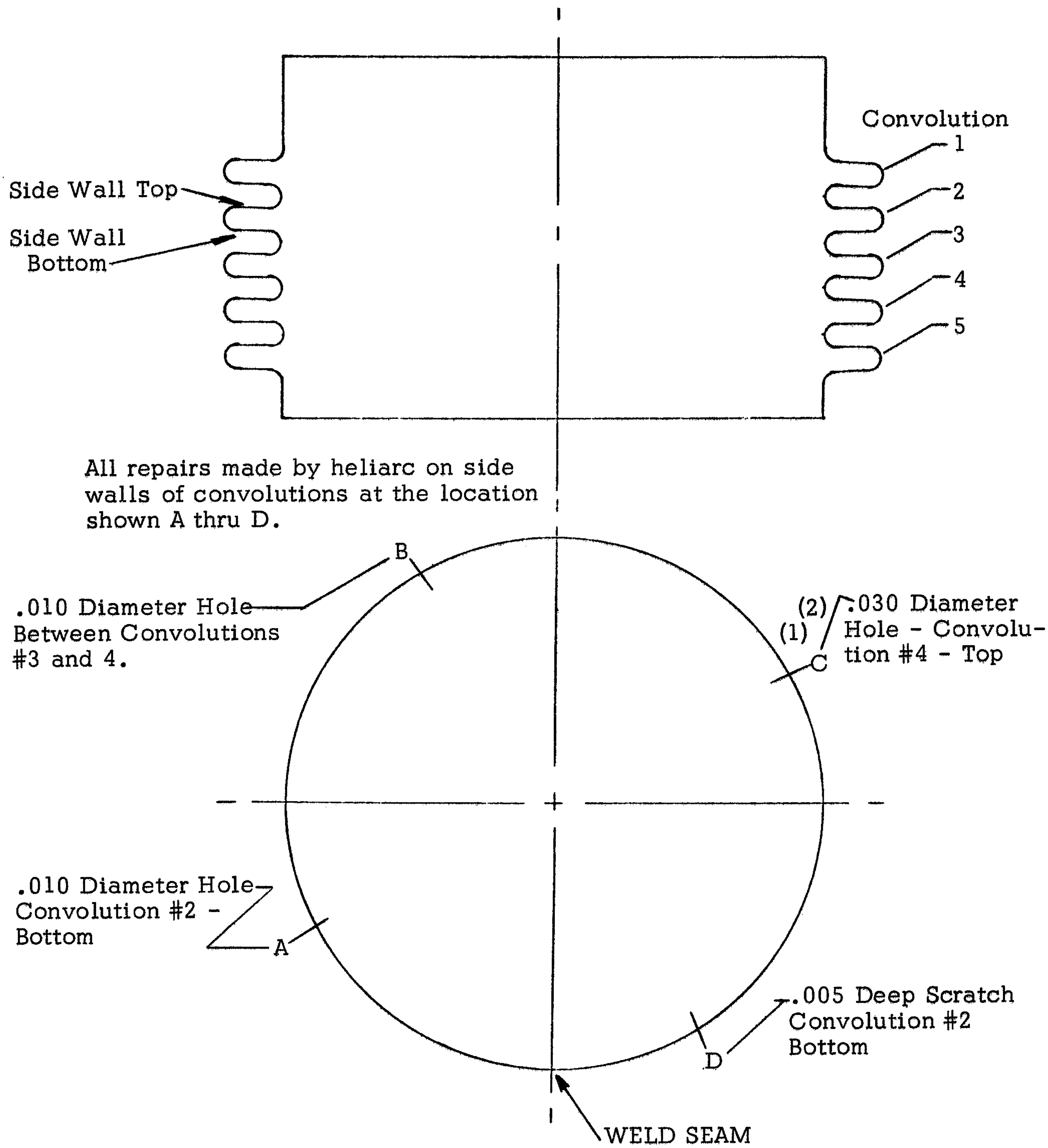


FAILURE

1. Repair A - 1670 cycles.
2. Repair C - 2730 cycles.
3. In root, parent material between Convolutions #4 & 5 - 5570 cycles.
4. In root, parent material between Convolutions #1 & 2 on longitudinal weld at 5720 cycles.

Figure 24. Heliarc Repair in Root of Convolution, I

SN 3

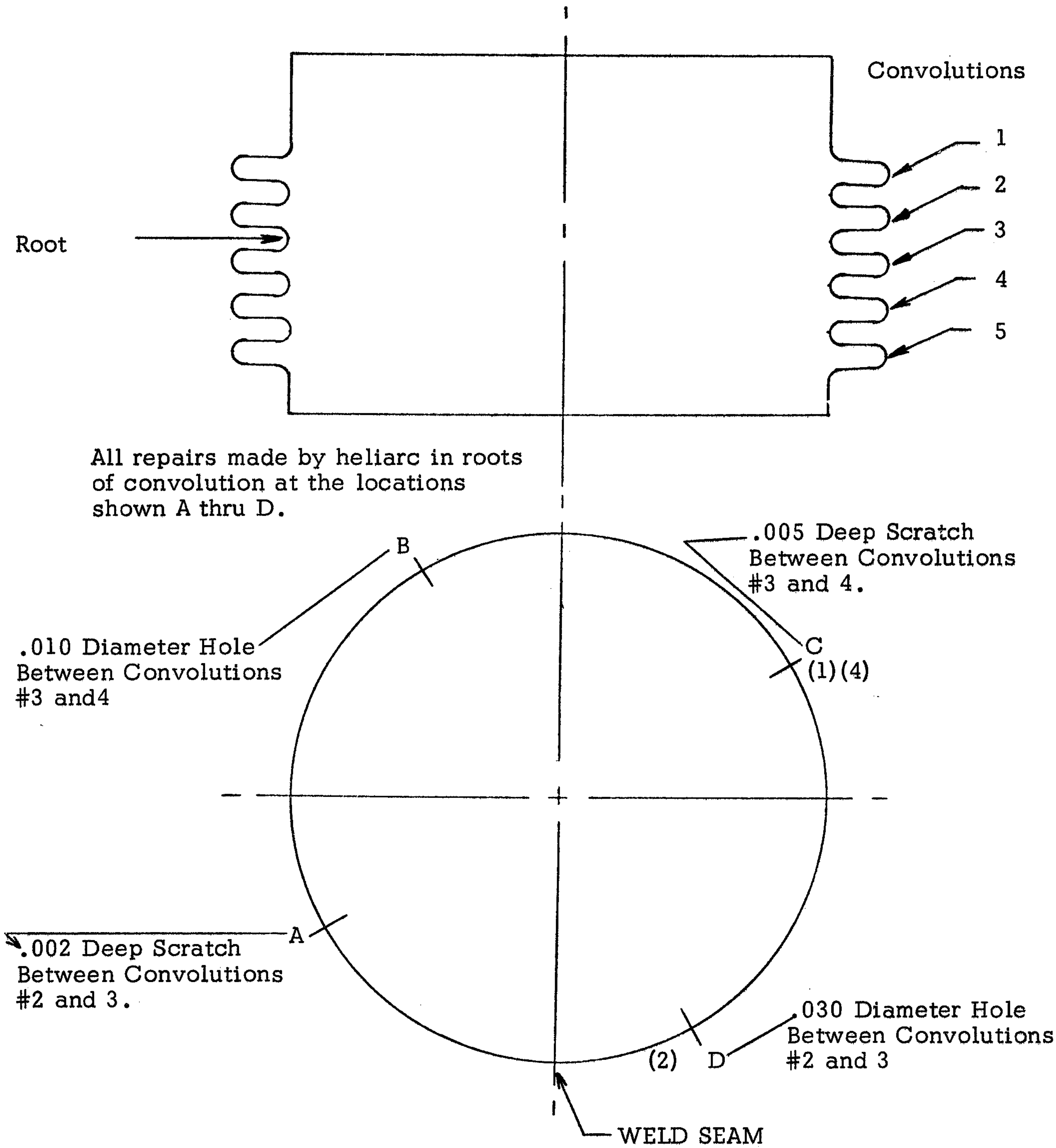


FAILURE

1. In root, parent material between Convolutions #3 and 4 - 5452 cycles.
2. In root, parent material between Convolutions #1 and 2 - 6180 cycles.

Figure 25. Heliarc Repair on Side of Convolution

SN 4



<u>FAILURE</u>

1. Repair C at 3272 cycles.
2. Between 4th and 5th convolutions, parent material 3505 cycles.
3. Between 4th and 5th convolutions, parent material 3989 cycles.
4. Between 4th and 5th convolutions, parent material 4336 cycles.

Figure 26. Heliarc Repair in Root of Convolution, II

JOB NO.	AMETEK / Straza 790 GREENFIELD DRIVE EL CAJON, CALIFORNIA	NO. 8-480077
FOR:		TYPE:
APPROVED BY:		DATE: 5/24/68
APPROVED BY:		REV. / DATE:
PREPARED BY:	CODE IDENT. 03024 / SPECIFICATION	

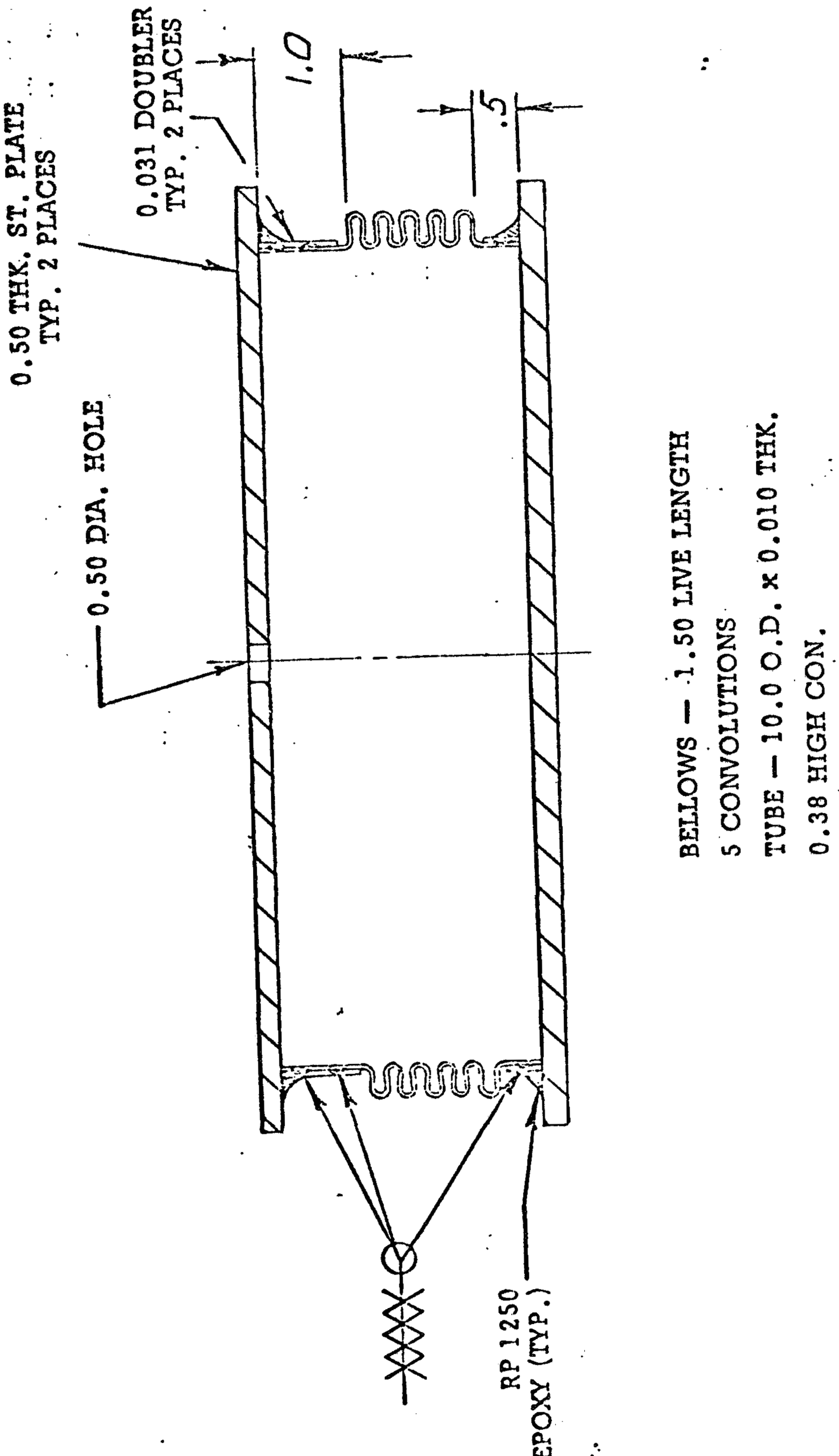


Figure 27. Bellows Test Specimen

VACUUM AND CO_2 JACKETED LINES REPAIR TECHNIQUES

KSC Study, NAS 10-6098, Task 3, Sub-Task 2

REPORT

PRELIMINARY REPAIR TECHNIQUE EVALUATION TEST 1

SUMMARY

It was determined from this series of tests on various leak repair materials that hole size can be critical to the ability of a material to seal the leak. Apparently the aerosol spray application is not suitable for the relatively large holes tested. The higher viscosity fluids such as Kinney "Kinseal" and Loctite 404 gave the best results in this category and the adhesive-backed lead foil and Temp-R-Tape also showed good potential. These tests are only an indication of merit and are not intended as a final evaluation of any material or method.

TESTING PHILOSOPHY

As a first step in developing useful testing techniques for the repair methods to be evaluated in the study program, it was decided that a representative group of repair methods would be chosen, attempted on samples, leak checked, flexure cycled and leak checked again. The purpose was three-fold: (a) to gain some idea of the ability of available materials to seal leaks with a pressure differential across the hole, (b) to evaluate the effects of flexure cycling some representative repair materials, and (c) to learn something of the criticality of hole size relative to repairability.

TEST SPECIMENS

Since one of the most frequent leakage problems is small holes in bellows assemblies, a CRES type 321 coupon of 0.020 in. thickness was chosen for testing. For ease of handling and convenience in flexure cycling the coupon was sized at 2.0 in. wide by 6.0 in. long. The smallest hole easily producible with in-plant equipment was a 80 drill size (0.013 in.). It was decided, however, to reduce the size of these holes further by center punching around the hole, thereby coming closer to what an actual leak might be. It was realized that a loss of uniformity of hole size would result but it was felt that if a reading was taken on the mass spectrometer to determine the minimum dynamic pressure obtainable with each specimen and if this information was noted on test results then these results would be meaningful when compared.

TEST EQUIPMENT

For checking leakage, an NRC 925 mass spectrometer was used. This unit has a maximum sensitivity of helium leakage down to 1×10^{-10} Standard cc/sec.

For flexure cycling each specimen was simply clamped in a vise as shown in Figure 1 with hole 2 in. from the clamp and using a fixed vernier caliper at the free end to determine flexure distance. The specimens were moved by hand.

TESTING REQUIREMENTS

Eleven test specimens were prepared for the eleven different repair methods. First, each specimen was placed over the evacuation port of the mass spectrometer and a reading taken of the pressure on the evacuated side of the specimen. This dynamic pressure reading is recorded for each specimen on Figure 2 tabulation under the column heading "Minimum Dynamic Pressure Obtainable with Unsealed Hole". The value given is in microns of mercury. Next, with the specimen still in place on the evacuation port, the repair material was applied. A reading of leakage rate with helium was then taken and this value is recorded in Figure 2. The specimen was then removed from the mass spectrometer and the repair material again applied whether the specimen leaked or not. The specimens were then allowed to sit for a one-hour cure cycle. They were then re-checked for helium leak rate, flexure cycled ten times, checked for helium leak rate, flexure cycled 50 times and again checked for helium leak rate. All these leak rates are recorded in the appropriate columns of Figure 2.

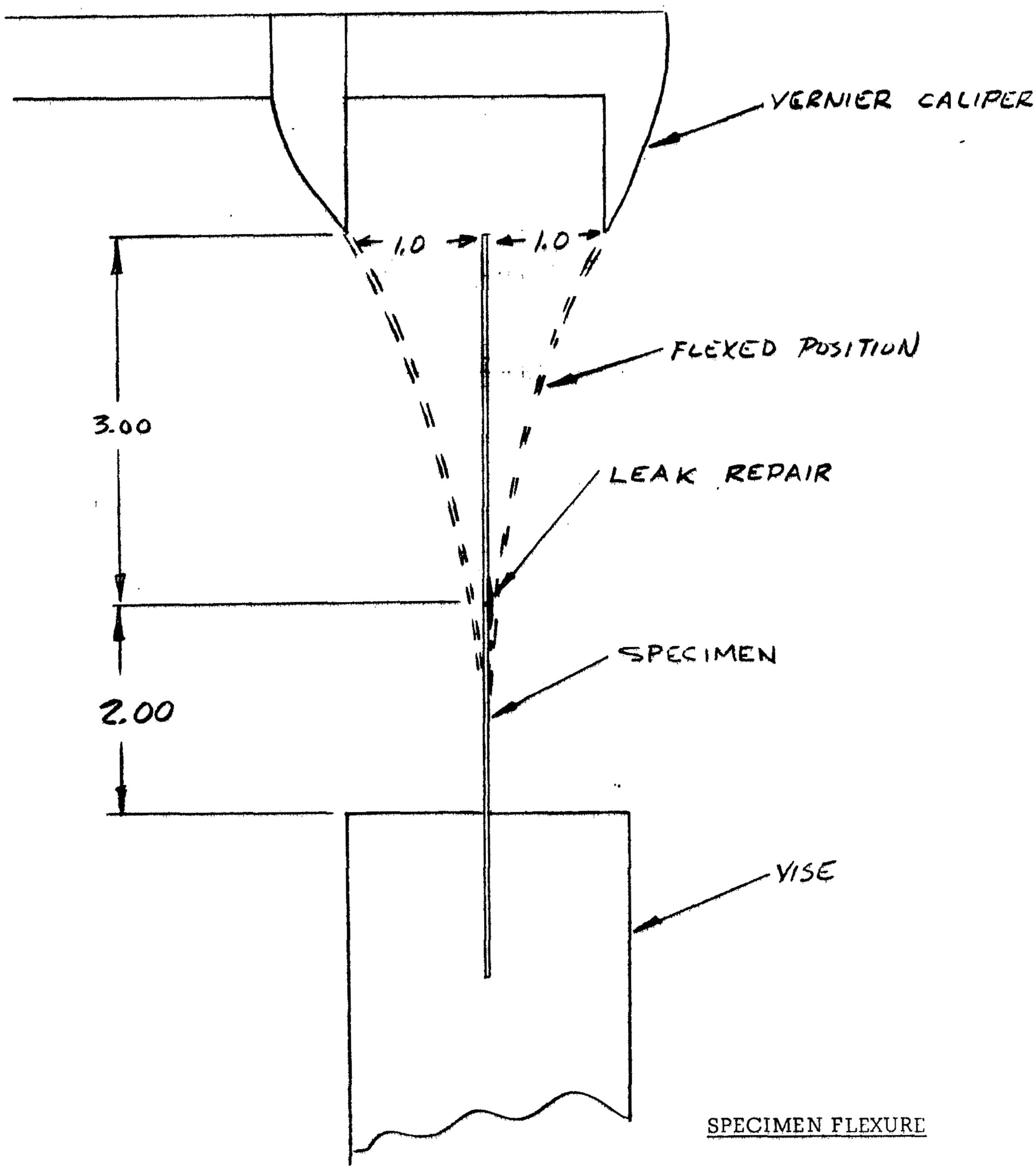


Figure 28. Specimen Flexure

PRELIMINARY EVALUATION OF LEAK SEAL MATERIALS

Specimen No.	Sealant Description	Minimum Dynamic Pressure Obtainable With Unsealed Hole (mic/mercury)	Leak Rate With Dynamic Patch (scc/sec of He)	Leak Rate With Ambient Patch (scc/sec of He)	Leak Rate 10 Cycles (scc/sec of He)	Leak Rate 50 Cycles (scc/sec of He)
1	Cryogenic Research Co. Aerosol Spray	25μ	$>5.4 \times 10^{-6}$	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$
2	CVC Celvaseal Bottle Applicator	300μ	$>5.4 \times 10^{-6}$	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$	$>5.4 \times 10^{-6}$
3	Krylon 1306 Aerosol Spray	40μ	$>5.4 \times 10^{-6}$	3.6×10^{-8}	4.8×10^{-8}	5.2×10^{-8}
4	Cryogenic Research Co. Vacuum Sealant Bottle Applicator	60μ	$>5.4 \times 10^{-6}$	4.0×10^{-9}	4.0×10^{-9}	4.0×10^{-9}
5	General Electric Co Bottle Applicator	25μ	$>5.4 \times 10^{-6}$	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$
6	Kinney Kinseal Bottle Applicator	5μ	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$
7	Temp-R-Tape	4μ	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$
8	Morgan Adhesive Co Lead Foil Tape	2μ	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$
9	Loctite 404	4μ	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$
10	Loctite 69-52	75μ	$<5 \times 10^{-7}$	$>5.4 \times 10^{-6}$	$>5.4 \times 10^{-6}$	$>5.4 \times 10^{-10}$
11	Physically closed hole by center punching around edges	0μ	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$	$<1 \times 10^{-10}$

Figure 29. Preliminary Evaluation of Leak Sealing Materials

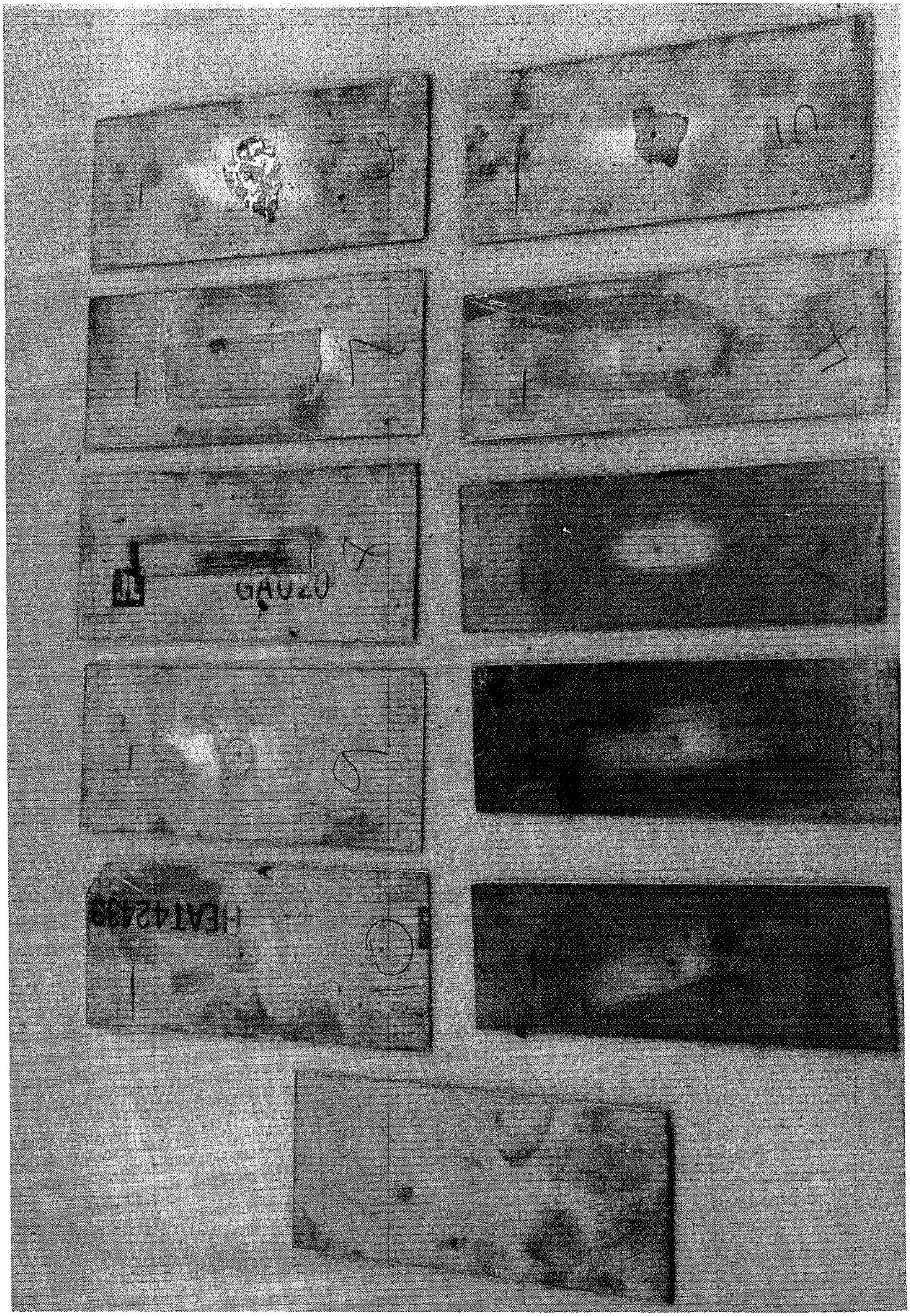


Figure 31. Repair Material Test Coupon Mass Spectrometer Leak Test

VACUUM AND CO_2 JACKETED LINES REPAIR TECHNIQUES

KSC Study, NAS 10-6098, Task 3, Sub-Task 2

REPORT

PRELIMINARY REPAIR TECHNIQUE EVALUATION TEST 2

SUMMARY

Although not intended to be conclusive, these tests do establish that at least temporary repairs can be made to large holes in vacuum lines (1/16 in. x 1/8 in.) with some degree of confidence. No special care or cleaning was involved and field conditions were assumed to exist for purposes of obtaining meaningful results.

TESTING PHILOSOPHY

This second group of tests was undertaken for the purpose of simulating damage which is typical of that actually encountered in service, then attempting repairs to such damage by means which could easily be used with the line in place. After such repair, leak testing, simulated flex cycling and a second leak check were applied as verification of integrity. No repair life criteria was applied since this testing was preliminary in nature and not part of the Phase II testing program. The purpose of this test was to establish the value of the approaches employed so that more extensive testing could be considered.

TEST SPECIMENS

The test specimen was a single bellows, 6.00 in. diameter x 4.00 in. long with 0.375 in. high convolutions. The bellows was one ply of 0.008 in. thick CRES type 321. This specimen was chosen for ease of damage application (and therefore controlled repeatability) as well as similarity to outer jackets of lines in service. This single specimen was used for all three repairs. The damage and repairs were spaced 120° apart around the circumference.

TEST EQUIPMENT

For checking leakage, an NRC 925 mass spectrometer was used. This unit has a maximum sensitivity of helium leakage down to 1×10^{-10} scc/sec.

For flexure cycling the specimen was placed between two plates and with a scale to measure motion, the top plate depressed manually the measured distance. The damage was applied using a wide blade screwdriver for the dent and a sharply pointed center punch to develop the hole.

TEST REQUIREMENTS

After bellows fabrication, the unit was placed on the mass spectrometer and checked for leakage. Observing that the specimen was helium tight, the first of the three damage/repair cycles was started. The Figure 4 tabulation shows the test results corresponding to each repair method along with comments. In each case the damage consisted of (1) a dent (sharply creased depression) of approximately 0.032 in. depth along the crown of the convolution and at a 45° angle to the bellows axial centerline and (2) a hole punched through the root of this dent approximately 0.093 in. diameter. After damage application in each of the three cases, the repair was made as follows:

REPAIR NO. 1 (see Figure 33)

Pressed the damaged portion of the convolution flat with pliers over a 1/2 in. long area. Wiped off area with clean rag. Wrapped a 1-1/2 in. long x 1/2 in. wide piece of adhesive backed lead foil tape over damaged area. Pressed tape firmly in place with fingers and screwdriver. Sprayed over patch with aerosol can cf Crown 202 high temperature aluminum paint. Let cure for 24 hours.

REPAIR NO. 2 (see Figure 34)

Wiped off damaged area with clean rag. Applied General Electric RTV 102 silicone rubber over entire damaged area approximately 1/32 in. to 1/16 in. thick. Allowed 2 hours cure time.

REPAIR NO. 3 (see Figure 35)

Wiped off damaged area with clean rag. Applied Johns-Manville "Albaseal" to damaged area approximately 1/16 in. thick. Applied a 1-1/4 in. long x 3/4 in. wide piece of CHR "Temp-R-Tape" over the Albaseal patch and pressed firmly in place with fingers and screwdriver. Applied General Electric Vacuum Leak Sealant over entire patch with small brush from bottle. Allowed 24 hours cure time.

After the repairs were made, the bellows was checked for leakage using a mass spectrometer helium leak detector calibrated to a sensitivity of 1×10^{-10} scc/sec. When no leakage was detected, the bellows was cycled axially to 1/2 in. compression and back to nominal 20 times and re-checked for leakage.

REPAIR METHOD TEST RESULTS

Specimen	Repair Description	Test Results	Comment
1	Flattened damaged convolution, lead foil tape, aluminum paint seal.	No Leak	When flattened, the convolution becomes higher exposing it to further damage.
2	G.E. RTV 102 Silicone Rubber	No Leak	The rubber provides impact barrier over damaged area. Adhesion appeared good.
3	J-M Albaseal, CHR Temp-R-Tape plus G.E. Vacuum Leak Sealant	No Leak	Tape did not conform to curvature, wrinkled several places.

Figure 32. Repair Method Test Results

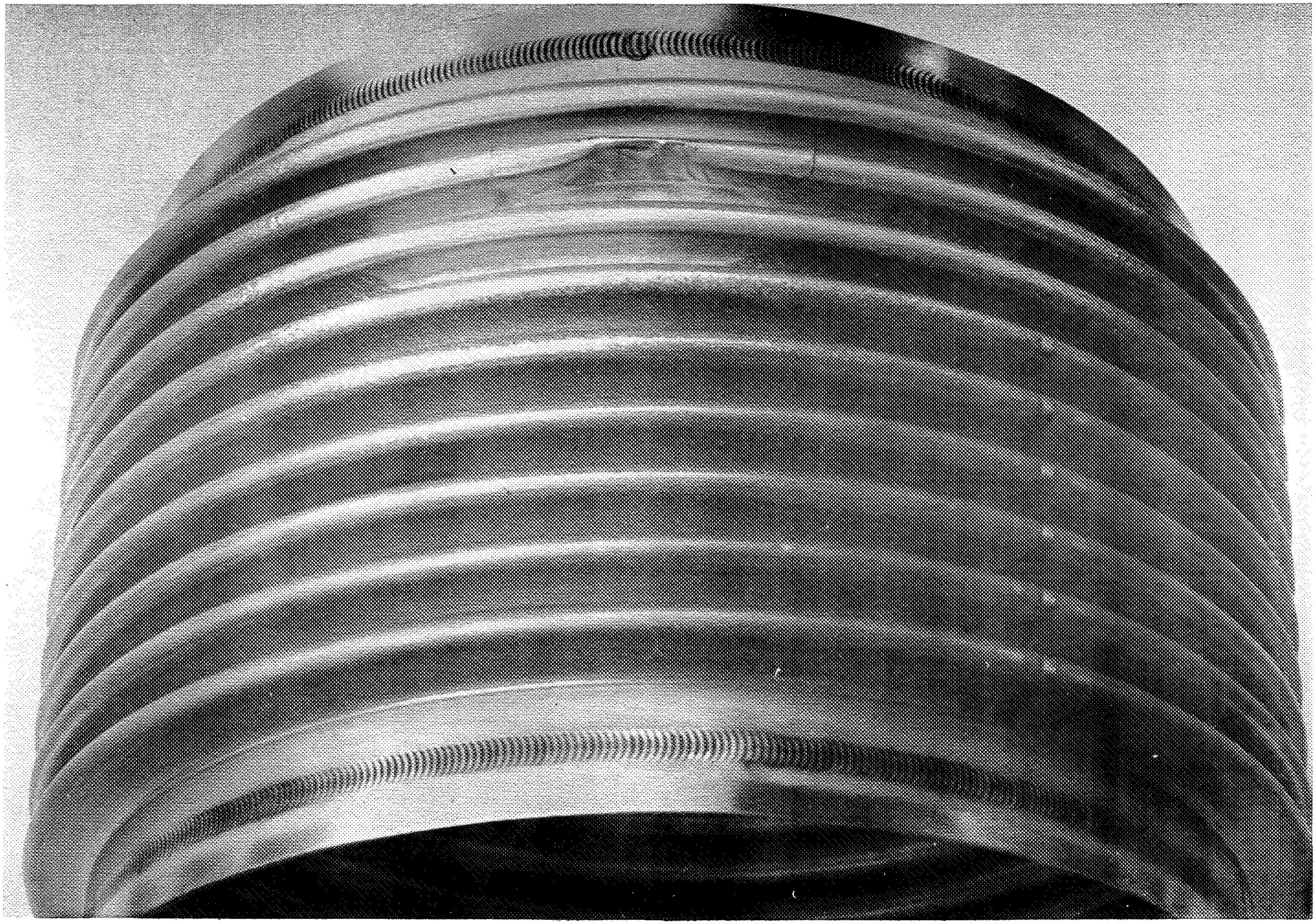


Figure 33. Preliminary Repair Evaluation Using Lead Foil Adhesive Backed Tape

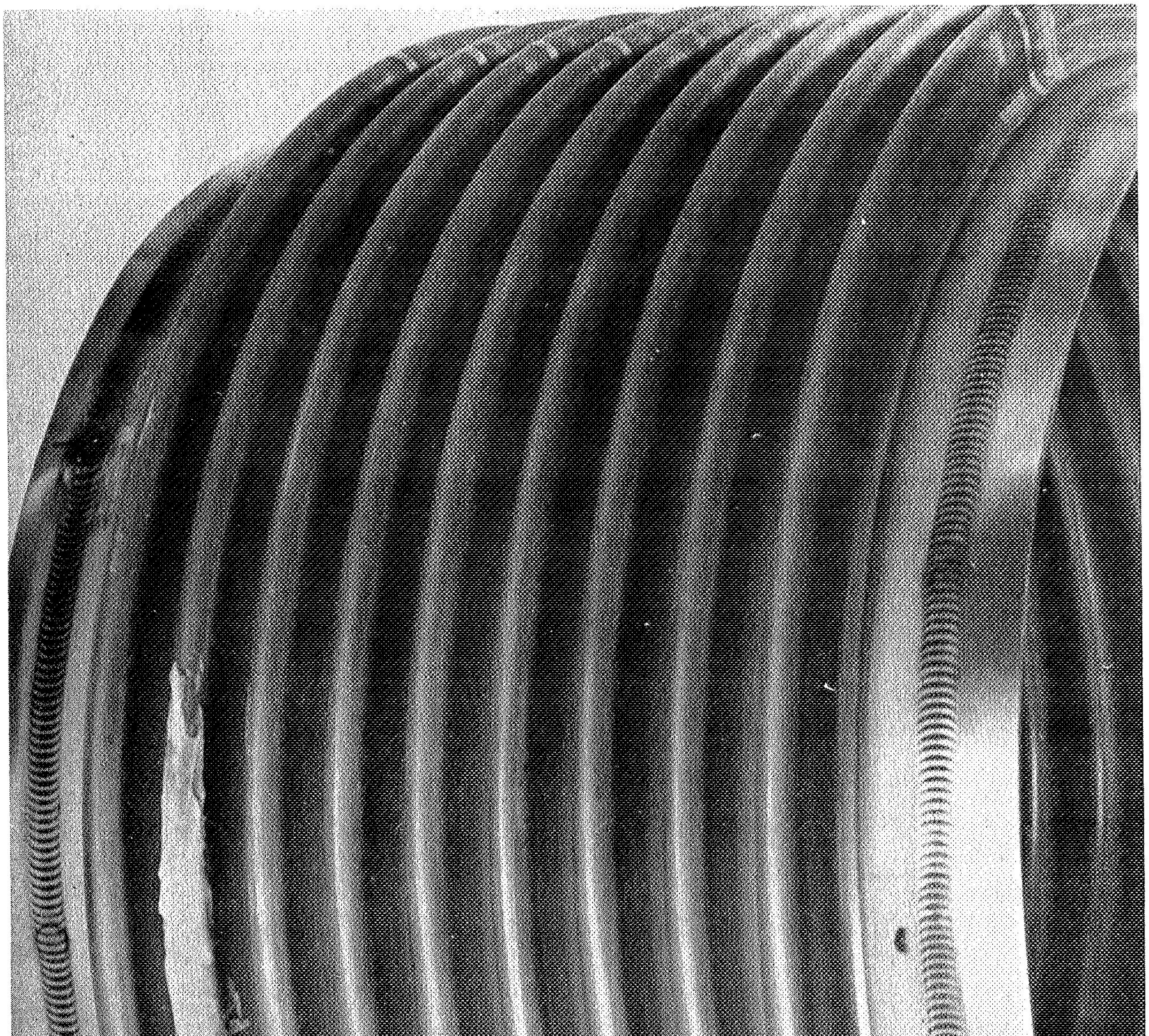


Figure 34. Preliminary Repair Evaluation Using RTV Silicone Rubber

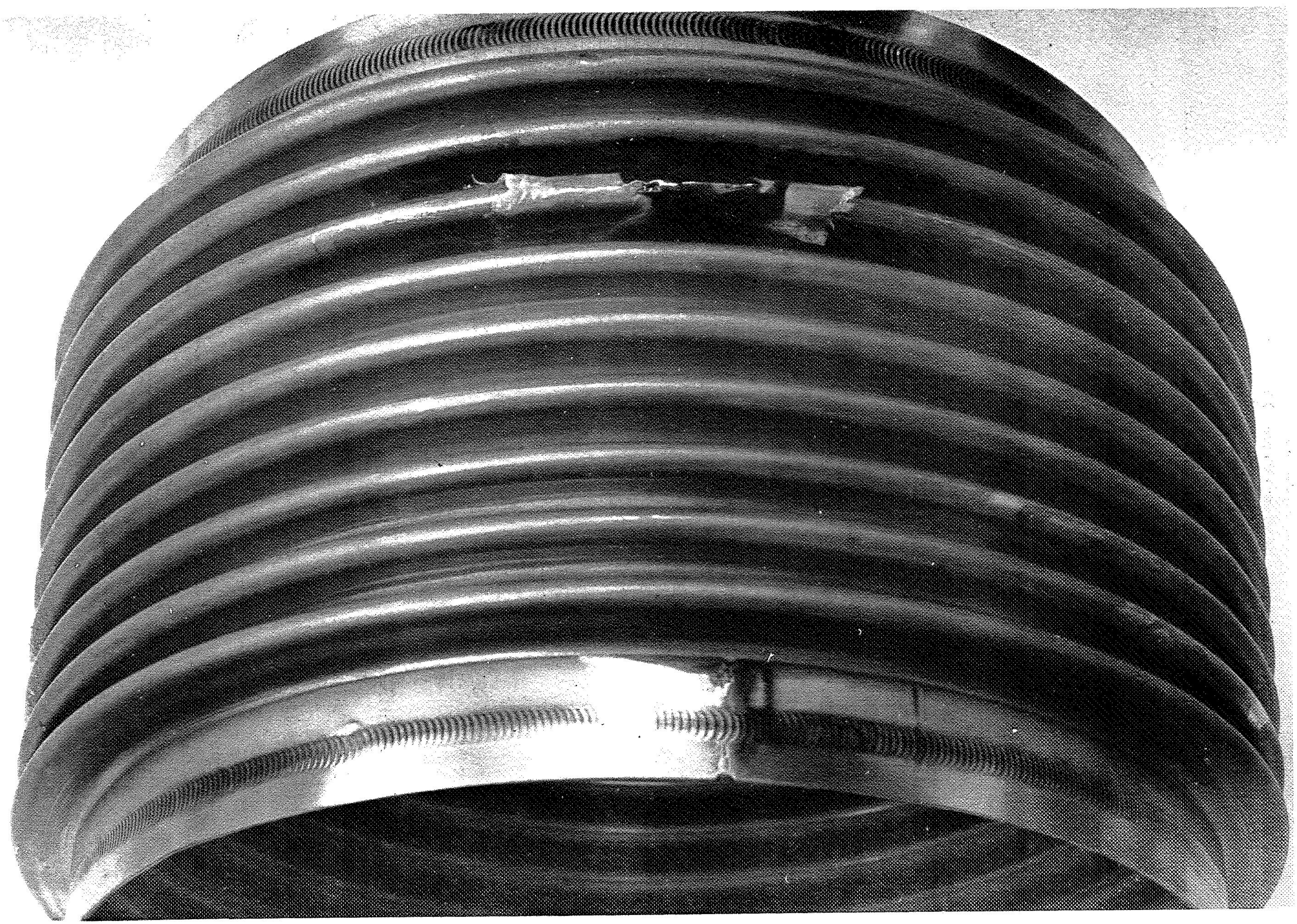


Figure 35. Preliminary Repair Evaluation Using J-M Duxseal and Teflon Tape

PRELIMINARY

REPAIR METHOD EVALUATION

Repair Method / Material: Narmco Cryogenic Cement

Heat Range Category: [XX] No [ ] Low [ ] Moderate [ ] High

Applicability

Temporary	[XX]	
Permanent	[XX] (Possible)	
Maximum Hole Size	[X] > .010 inch dia.	[ ] < .010 inch dia
Bellows	[X] Yes	[ ] No
Straight Pipe	[X] Yes	[ ] No
Vacuum Line	[X] Yes	[ ] No
Pressure Line	[ ] Yes (Possible)	[ ] No

Equipment Required: Mixing pot for two part constituents

Effects of the Repair

Reliability	[ ] No Change		[XX] Lower
Contamination	[ ] Insignificant		[X] Possible Problem
Ruggedness	[ ] Increase	[XX] Decrease	[ ] No Change
Repairability (of Repair)	[ ] Good	[XX] Poor	[ ] Impossible

System down time: Pump down time

Total Repair Time: Approx. 30 minutes to one hour

Comments: It is doubtful whether this method could be applied to line with vacuum integrity intact due to low viscosity of mixture initially.

PRELIMINARY

REPAIR METHOD EVALUATION

Repair Method / Material: Loctite Sealant (Various types)

Heat Range Category: [X] No [ ] Low [ ] Moderate [ ] High

Applicability

Temporary	[ ]			
Permanent	[XX]	(Probably)		
Maximum Hole Size	[X]	$>$.010 inch dia.	[ ]	$<$.010 inch dia.
Bellows	[XX]	Yes	[ ]	No
Straight Pipe	[X]	Yes	[ ]	No
Vacuum Line	[X]	Yes	[ ]	No
Pressure Line *	[X]	Yes (Possibly)	[ ]	No

Equipment Required: None

Effects of the Repair

Reliability	[ ]	No Change			[X]	Lower (Possibly) slight
Contamination	[X]	Insignificant			[ ]	Possible Problem
Ruggedness*	[ ]	Increase	[ ]	Decrease	[ ]	No Change
Repairability (of Repair)	[XX]	Good (Solvent Proven)	[ ]	Poor	[ ]	Impossible

System down time: Pump down time

Total Repair Time: Less than 30 minutes for most grades

Comments: * Must be tested

PRELIMINARY

REPAIR METHOD EVALUATION

Repair Method / Material: Loctite Bonding Agents (Various types)

Heat Range Category: [xx] No [ ] Low [ ] Moderate [ ] High

Applicability

Temporary	[ ]		
Permanent	[xx] (Possible)		
Maximum Hole Size	[xx] >.010 inch dia.	[ ]	<.010 inch dia.
Bellows	[xx] Yes	[ ]	No
Straight Pipe	[xx] Yes	[ ]	No
Vacuum Line	[xx] Yes	[ ]	No
Pressure Line	[xx] Yes (Possibly)	[ ]	No

Equipment Required: mixing container for some types

Effects of the Repair

Reliability	[ ] No Change		[xx] Lower (Possibly slight)
Contamination	[xx] Insignificant		[ ] Possible Problem
Ruggedness*	[ ] Increase	[ ] Decrease	[ ] No Change
Repairability (of Repair)	[xx] Good (solvent proven)	[ ] Poor	[ ] Impossible

System down time: Pump down time

Total Repair Time: Less than 30 minutes

Comments: * Test must be used to determine

PRELIMINARY
REPAIR METHOD EVALUATION

Repair Method / Material: J-M Volseal, Albaseal, Modrseal, Duxseal, etc.

Heat Range Category: [XX] No [ ] Low [ ] Moderate [ ] High

Applicability

Temporary	[XX]			
Permanent	[ ]			
Maximum Hole Size	[XX]	> .010 inch dia.	[ ]	< .010 inch dia.
Bellows	[XX]	Yes	[ ]	No
Straight Pipe	[XX]	Yes	[ ]	No
Vacuum Line	[XX]	Yes	[ ]	No
Pressure Line	[ ]	Yes	[XX]	No

Equipment Required: None

Effects of the Repair

Reliability			[ ]	No Change	[XX]	Lower
Contamination			[ ]	Insignificant	[XX]	Possible Problem
Ruggedness	[ ]	Increase	[XX]	Decrease	[ ]	No Change
Repairability (of Repair)	[XX]	Good	[ ]	Poor	[ ]	Impossible

(if thorough cleaning is used)

System down time: Pump down time.

Total Repair Time: Less than 15 minutes

Comments: Deterioration in environmental conditions over long periods of time is unknown.

PRELIMINARY

REPAIR METHOD EVALUATION

Repair Method / Material: Kinney "Kinseal"

Heat Range Category: [XX] No [ ] Low [ ] Moderate [ ] High

Applicability

Temporary	[X]			
Permanent	[ ]			
Maximum Hole Size	[ ]	> .010 inch dia.	[X]	< .010 inch dia.
Bellows	[XX]	Yes	[ ]	No
Straight Pipe	[XX]	Yes	[ ]	No
Vacuum Line	[XX]	Yes	[ ]	No
Pressure Line	[ ]	Yes	[XX]	No

Equipment Required: None

Effects of the Repair

Reliability	[ ] No Change		[XX] Lower
Contamination	[XX] Insignificant		[ ] Possible Problem
Ruggedness	[ ] Increase	[XX] Decrease	[ ] No Change
Repairability (of Repair)	[ ] Good	[XX] Poor (difficult to remove)	[ ] Impossible

System down time: Pump down time

Total Repair Time: Less than 15 minutes

Comments

PRELIMINARY

REPAIR METHOD EVALUATION

Repair Method / Material   Temp-R-Tape

Heat Range Category   [xx] No   [ ] Low   [ ] Moderate   [ ] High

Applicability

Temporary	[xx]	
Permanent	[ ]	
Maximum Hole Size	[xx] $>$ .010 inch dia.	[ ] $<$ .010 inch dia.
Bellows	[xx] Yes	[ ] No
Straight Pipe	[xx] Yes	[ ] No
Vacuum Line	[xx] Yes	[ ] No
Pressure Line	[ ] Yes, (Possible)	[ ] No

Equipment Required

Effects of the Repair

Reliability	[ ] No Change		[XX] Lower
Contamination	[xx] Insignificant		[ ] Possible Problem
Ruggedness	[ ] Increase	[XX] Decrease	[ ] No Change
Repairability (of Repair)	[xx] Good	[ ] Poor	[ ] Impossible

System down time   Pump down time

Total Repair Time   Less than 15 minutes

Comments   Probably would have to be sealed with painted vacuum sealant around tape.

PRELIMINARY

REPAIR METHOD EVALUATION

Repair Method / Material: Adhesive Backed Lead Foil

Heat Range Category: [XX] No [ ] Low [ ] Moderate [ ] High

Applicability

Temporary	[XX]			
Permanent	[X] (Possibly)			
Maximum Hole Size	[XX] > .010 inch dia.		[ ]	< .010 inch dia.
Bellows	[XX] Yes		[ ]	No
Straight Pipe	[XX] Yes		[ ]	No
Vacuum Line	[XX] Yes		[ ]	No
Pressure Line	[XX] Yes (Possibly)		[ ]	No

Equipment Required

Effects of the Repair

Reliability		[ ] No Change	[XX]	Lower
Contamination		[XX] Insignificant	[ ]	Possible Problem
Ruggedness	[ ] Increase	[XX] Decrease	[ ]	No Change
Repairability (of Repair)	[XX] Good	[ ] Poor	[ ]	Impossible

System down time: Pump down time

Total Repair Time: Less than 15 minutes

Comments

PRELIMINARY

REPAIR METHOD EVALUATION

Repair Method / Material "Grip" Dental Cement

Heat Range Category [xx] No [ ] Low [ ] Moderate [ ] High

Applicability

Temporary	[xx]		
Permanent	[xx] (Possibly)		
Maximum Hole Size	[xx] $>$.010 inch dia.	[ ]	$<$.010 inch dia.
Bellows *	[ ] Yes	[ ]	No
Straight Pipe	[x] Yes	[ ]	No
Vacuum Line	[x] Yes	[ ]	No
Pressure Line *	[ ] Yes	[ ]	No

Equipment Required None

Effects of the Repair

Reliability		[ ] No Change	[xx] Lower
Contamination		[ ] Insignificant	[xx] Possible Problem
Ruggedness	[ ] Increase	[x] Decrease	[ ] No Change
Repairability (of Repair)	[ ] Good	[xx] Poor (difficult removal)	[ ] Impossible

System down time Pump down time

Total Repair Time Less than 30 minutes

Comments * Must be tested

PRELIMINARY

REPAIR METHOD EVALUATION

Repair Method / Material: Dekhotinsky Cement

Heat Range Category: ☐ No ☒ Low ☐ Moderate ☐ High

Applicability

Temporary	☒	
Permanent	☒ (Possible)	
Maximum Hole Size	☒ $>$ .010 inch dia.	☐ $<$ .010 inch dia.
Bellows *	☐ Yes	☐ No
Straight Pipe	☒ Yes	☐ No
Vacuum Line	☒ Yes	☐ No
Pressure Line *	☐ Yes	☐ No

Equipment Required: Hand torch or other 300°F Heat Source

Effects of the Repair

Reliability	☐ No Change		☒ Lower
Contamination	☒ Insignificant		☐ Possible Problem
Ruggedness	☐ Increase	☒ Decrease	☐ No Change
Repairability (of Repair)	☐ Good	☒ Poor	☐ Impossible

System down time: Pump down time

Total Repair Time: Approx. 1/2 hour

Comments: * Testing required to determine

PRELIMINARY

REPAIR METHOD EVALUATION

Repair Method / Material Indium Solder (Various types)

Heat Range Category [ ] No [xx] Low [ ] Moderate [ ] High

Applicability

Temporary	[xx]			
Permanent	[xx]			
Maximum Hole Size	[xx]	> .010 inch dia.	[ ]	< .010 inch dia.
Bellows	[xx]	Yes	[ ]	No
Straight Pipe	[xx]	Yes	[ ]	No
Vacuum Line	[xx]	Yes	[ ]	No
Pressure Line	[xx]	Yes (Probably)	[ ]	No

Equipment Required Hand torch

Effects of the Repair

Reliability			[ ]	No Change	[xx]	Lower
Contamination			[xx]	Insignificant	[ ]	Possible Problem
Ruggedness	[ ]	Increase	[xx]	Decrease	[ ]	No Change
Repairability (of Repair)	[xx]	Good	[ ]	Poor	[ ]	Impossible

System down time Pump down time +

Total Repair Time Approx. 1/2 hour

Comments Adhesion of solder is dependent on operator skill in cleaning and preparation of surface and heat application

PRELIMINARY

REPAIR METHOD EVALUATION

Repair Method / Material 60/40 Soft Solder (Tin/Lead)

Heat Range Category [ ] No [xx] Low [ ] Moderate [ ] High

Applicability

Temporary	[xx]			
Permanent	[xx]			
Maximum Hole Size	[xx]	> .010 inch dia.	[ ]	< .010 inch dia.
Bellows	[xx]	Yes	[ ]	No
Straight Pipe	[xx]	Yes	[ ]	No
Vacuum Line	[xx]	Yes	[ ]	No
Pressure Line	[xx]	Yes	[ ]	No

Equipment Required Acid brush, acid, torch (370°F Min)

Effects of the Repair

Reliability			[ ] No Change		[xx]	Lower
Contamination			[xx] Insignificant		[ ]	Possible Problem
Ruggedness	[ ] Increase		[xx] Decrease		[ ]	No Change
Repairability (of Repair)	[xx] Good (with care in cleanup)		[ ] Poor		[ ]	Impossible

System down time Pump down time +

Total Repair Time 1/2 to 1 hour

Comments Operator trining & skill are important

PRELIMINARY

REPAIR METHOD EVALUATION

Repair Method / Material: Silvaloy #35 & #45 Braze

Heat Range Category: ☐ No ☐ Low ☒ Moderate ☐ High

Applicability

Temporary	☐			
Permanent	☒			
Maximum Hole Size	☒	> .010 inch dia.	☐	< .010 inch dia.
Bellows	☒	Yes	☐	No
Straight Pipe	☒	Yes	☐	No
Vacuum Line	☒	Yes	☐	No
Pressure Line	☒	Yes	☐	No

Equipment Required: $1500^{\circ}F$ Torch

Effects of the Repair

Reliability	☐	No Change			☒	Lower (Slightly)
Contamination	☒	Insignificant			☐	Possible Problem
Ruggedness	☐	Increase	☐	Decrease	☒	No Change
Repairability (of Repair)	☒	Good (if brazing is used)	☐	Poor	☐	Impossible

System down time: Pump down time +

Total Repair Time: Approx. 1 hour

Comments

PRELIMINARY

REPAIR METHOD EVALUATION

Repair Method / Material   Heliarc Welding

Heat Range Category   [ ] No   [ ] Low   [ ] Moderate   [XX] High

Applicability

Temporary	[ ]			
Permanent	[XX]			
Maximum Hole Size	[XX]	> .010 inch dia.	[ ]	< .010 inch dia.
Bellows	[XX]	Yes	[ ]	No
Straight Pipe	[XX]	Yes	[ ]	No
Vacuum Line	[XX]	Yes	[ ]	No
Pressure Line	[XX]	Yes	[ ]	No

Equipment Required   Helium & Argon Gas, Power Supply, Face Mask, Torch, Hoses.

Effects of the Repair

Reliability			[ ]	No Change	[XX]	Lower (Only slight
Contamination			[XX]	Insignificant	[ ]	Possible Problem
Ruggedness	[ ]	Increase	[ ]	Decrease	[XX]	No Change
Repairability (of Repair)	[XX]	Good	[XX]	Poor	[ ]	Impossible

Depends on thickness of material, if thin bellows are repaired then heat can be problem.

System down time   Pump down time +

Total Repair Time   2 to 3 hours

Comments   Operator training & skill are critical: fitter must accompany welder, equipment weight precludes repair "in place"

PRELIMINARY

REPAIR METHOD EVALUATION

Repair Method / Material: General Electric RTV 102 Silicone Rubber; General Electric S.E. 1201 Silicone Sealant; Dow Corning #732 RTV; Dow Corning 93-500 RTV Encapsulant

Heat Range Category: [X] No [ ] Low [ ] Moderate [ ] High

Applicability

Temporary	[X]	
Permanent	[X] (Possible)	
Maximum Hole Size	[X] > .010 inch dia.	[ ] < .010 inch dia.
Bellows	[X] Yes	[ ] No
Straight Pipe	[X] Yes	[ ] No
Vacuum Line	[X] Yes	[ ] No
Pressure Line *	[ ] Yes (doubtful)	[X] No

Equipment Required: None

Effects of the Repair

Reliability	[ ] No Change		[X] Lower (Possibly slight
Contamination	[X] Insignificant		[ ] Possible Problem
Ruggedness*	[ ] Increase	[ ] Decrease	[ ] No Change
Repairability (of Repair)	[X] Good	[ ] Poor	[ ] Impossible

System down time: None except possible pump-down or charging time

Total Repair Time: Less than 15 minutes

Comments: * Testing must determine.

3.8 PHASE II PROGRAM

3.8.1 Introduction

This document describes the results of AMETEK/Straza's "Repair Material Evaluation" (8-480093) and "Simulated Repair" (8-480094) Test Procedures. As stated in the Test Plan proposed in the Phase I Technical Report, a two stage approach was the most efficient in achieving preliminary evaluation of a large number of candidate repair materials. With the results of this data, selecting and fully evaluating the most promising materials was completed. This testing program is the major effort of Phase II, Task 3, Sub-task 2, for the NAS 10-6098 contract. The logical conclusion of this testing is selection of proven vacuum leak repair materials and methods which can be recommended for use in the field of vacuum and/ or CO_2 jacketed lines such as employed on the Launch Umbilical Towers at Complex 39.

3.8.2 Phase II Test Report

3.8.2.1 Applicable Documents

The following documents of the revision noted, were utilized as part of this testing program. Where any conflicts exist, the AMETEK/Straza Test Procedures govern.

Number and Description	Source
8-480093 Repair Materials Evaluation Test Procedure	AMETEK/Straza
8-480094 Simulated Repair Test Procedure	AMETEK/Straza
P4058-XX Field Repair Procedure(s)	AMETEK/Straza
KSC-STD-164D Environmental Test Methods	John F. Kennedy Space Flight Center

3.8.2.2 Item Description

Two basic configurations of test specimens were employed. For the Repair Material Evaluation, 2 inch x 7 inch x .015 inch thick type 316 CRES coupons were used. For the Simulated Repair Testing, bellows of type 316 CRES, 5 inches free length, 6 inches inside diameter, 0.35 inch convolution height, .016 inch wall thickness, single ply, 20 total convolutions were used.

Although it was originally anticipated that rigid pipe specimens might serve some purpose in the Simulated Repair Testing, evaluation of their use indicates otherwise. There would be little information concerning a repair material or method which could be developed with rigid pipe specimens which would not also be obtained with the bellows.

3.8.2.3 Repair Materials

Based on the findings in the Phase I Technical Report, the following materials were selected for preliminary Repair Material Evaluation:

Dow Corning #732 RTV Silicone Rubber
Narmco Cryogenic Cement #3135 Resin, #7111 Catalyst
General Electric RTV 102 Silicone Rubber
Loctite Sealant #54-52
Loctite Adhesive #2508
Loctite Sealant #69-52
Loctite "Plastic Gasket" Compound
Loctite Compound #75-21
Dow Corning #39-500 Encapsulant
Dekhotinsky Cement (Sealstix Brand)
Indium Solder (Indalloy Alloys 1 thru 10 & 13)
3M Co. Lead Foil Tape #420 - Adhesive backed
Teflon Tape 2 Mil thick - Adhesive backed
J-M Duxseal, Nordseal, Volseal and Albaseal
Tungsten Insert Gas (TIG) Welding with CRES 316L
Soft Solder 60/40 ASTM 60A

3.8.2.4 Preliminary Repair Procedures

Based on manufacturer's recommendations, knowledge of field conditions and types of repair work needed, Field Repair Procedures were written for each repair material. Each procedure is a three page document on identical formats. The procedure numbers all have the basic four digits (4058) followed in sequence by 1, 2, 3, ...etc. A letter follows the procedure number (A, B, C or D) to indicate heat level of application. These procedures are included here for reference.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P4058-1A

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Dow Corning #732 RTV (Silicone Rubber)

Equipment Required

None

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

Wipe entire area on and 1.0" (min.) adjaçent to repair with clean Kimwipe dipped in acetone to remove grease and contaminants. Allow to dry completely.

2. Safety precautions.

Un-cured silicone rubber releases acetic acid. In case of contact, flush with water immediately. Eye tissue can be permanently damaged.

3. Application of repair (Technique).

Fill damaged area with 1/16 to 1/8 inch thick coat by squeezing tube and moving nozzle close to repair area. Make coating an even thickness extending .250 to .500 inch beyond hole in all directions. Sealant is non-flowing after 10 minutes. Allow one hour for cure and 24 hours for full strength.

4. Post-repair cleaning, precautions, checks, etc.

None

5. Re-repair preparation of unsuccessful repair area.

Cut or peel off as much as possible of the old sealant, removing any foreign matter. Take care to use clean blade or other tool for this purpose.

6. Re-repair application technique.

Starting with step 1 of the procedure, continue as with new repair.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P 4058-2B

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Narmco Cryogenic Cement - (two part)

#7111 Curing Agent

#3135 Base Resin

Equipment Required

Heat Gun

Mixing Container

Spatula

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

   Wipe area of repair with trichloroethylene on clean kimwipe to remove all grease and foreign matter.

2. Safety precautions.

   Avoid skin contact with Resin and Curing Agent. Provide ventilation in area. . Do not breathe fumes. If skin is contacted, flush with denatured alcohol, then soap and water. Keep away from heat and open flame.

3. Application of repair (Technique).

   Mix equal parts of resin and curing agent in container. Stir thoroughly. Heat metal surface of repair area to 100°F. (approx.). Apply .032 to .062 inch thick patch over an area extending .250 to .500 inch beyond hole edges. Allow 1 hour to cure.

4. Post-repair cleaning, precautions, checks, etc.

   Depending on hole size, check to see if adhesive has dripped through.

5. Re-repair preparation of unsuccessful repair area.

Using heat gun on patch area, apply approximately 200^{O}F, wiping off cement.

6. Re-repair application technique.

Starting with Step 1 of the procedure follow sequence as given for original repair.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P 4058-3A

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

General Electric RTV 102 Silicone Sealant (silicone rubber)

Equipment Required

None

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

Wipe entire area on and 1.0" (minimum) adjacent to repair with clean Kimwipe dipped in acetone to remove grease and contaminants. Allow to dry completely.

2. Safety precautions.

Un-cured silicone rubber released acetic acid. In case of contact flush with water immediately. Eye tissue can be permanently damaged.

3. Application of repair (Technique).

Fill damaged area with .032 to .062 inch thick coat by squeezing tube and moving nozzle close to repair area. Make coating an even thickness extending .250 to .500 inch beyond hole in all directions. Sealant is non-flowing after 10 minutes. Allow one hour for cure and 24 hours for full strength.

4. Post-repair cleaning, precautions, checks, etc.

None.

5. Re-repair preparation of unsuccessful repair area.

Cut or peel off as much as possible of the old sealant, removing any foreign matter. Take care to use clean blade or other tool for this purpose.

6. Re-repair application technique.

Start with Step 1 of the procedure and continue as on first repair.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P 4058-4B

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Loctite Refrigerant Sealant No. 54-52

Equipment Required

Heat Gun

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

   Wipe area of repair with trichloroethylene on clean Kim-wipe to remove all grease and foreign matter.

2. Safety precautions.

   Avoid contact with eyes. Flush with water immediately if contacted.

3. Application of repair (Technique).

   Apply thin layer from plastic nozzle to repair area extending 1/4 inch minimum from hole edges. Apply $200^{\circ}F$ heat (approx.) to sealant for five minutes. Allow one hour to harden.

4. Post-repair cleaning, precautions, checks, etc.

   None

5. Re-repair preparation of unsuccessful repair area.

Heat sealed area to 400°F with heat gun and scrape off as much old sealant as possible. After cooling to room temperature, wipe with trichloroethylene to remove as much old sealant and foreign matter as possible.

6. Re-repair application technique.

Starting with Step 1 of the procedure, continue as with new repair.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P 4058-5B

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Loctite Epoxy Adhesive #2508 (pre-proportioned)

Equipment Required

Loctite #2508 Mixer cup kit

Heat Gun

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

   Wipe off area of repair with trichloroethylene on clean Kimwipe to remove all grease and foreign matter.

2. Safety precautions.

   Avoid vapors or prolonged skin contact. Wash contact areas with soap and warm water immediately.

3. Application of repair (Technique).

   Take one mixing pot from box, peel off film cover, push down pack bottom. Using spatula in kit, mix the two components thoroughly. Apply in thin (approximately 1/16 inch) layer over damaged area evenly approximately 1/4 inch beyond hole edges. Using heat gun apply 250°F for five minutes. Allow one hour for set-up.

4. Post-repair cleaning, precautions, checks, etc.

   Before curing, any excess may be removed with Methyl Ethyl Ketone

5. Re-repair preparation of unsuccessful repair area.

Clean off original repair with Methyl Ethyl Ketone to remove all foreign matter.

6. Re-repair application technique.

Starting with Step 1 of the procedure, follow same procedure as for original repair.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P 4058-6A

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Loctite Hydraulic Sealant No 69-52

Equipment Required

None

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

   Wipe area of repair with trichloroethylene on clean Kim-wipe to remove all grease and foreign matter.

2. Safety precautions.

   Avoid contact with eyes. Flush with water immediately if contacted.

3. Application of repair (Technique).

   Apply thin layer from plastic nozzle to repair area extending 1/4 inch minimum from hole edges. Allow one hour to harden

4. Post-repair cleaning, precautions, checks, etc.

   Check for bleed through into holes.

5. Re-repair preparation of unsuccessful repair area.

Scrape off loose repair material

6. Re-repair application technique.

Starting with Step 1, follow procedure for original repair.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P 4058-7A

Heat Range Category

A - No heat
B - Low heat
C - Moderate heat
D - High heat

Basic Material(s) of Repair

Loctite Plastic Gasket
Locquic Primer Grade Q

Equipment Required

None

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

   Wipe repair surface with trichloroethylene on clean Kimwipe to remove all grease and foreign matter.

2. Safety precautions.

   Keep primer away from heat sources, avoid breathing vapors, use adequate ventilation.

3. Application of repair (Technique).

   Spray cleaned surface of repair area with Locquic Grade Q Primer. Allow 2 minutes to dry. Spread thin (.062 inch) layer of plastic gasket from applicator - container. Extend layer 1/4 inch minimum beyond hole edges. Allow one hour to harden.

4. Post-repair cleaning, precautions, checks, etc.

   Check for full cure by pressing gently with clean probe.

5. Re-repair preparation of unsuccessful repair area.

Using Loctite "partsaver" brand safety solvent or acetone, remove old repair material and wipe metal clean with Kimwipe.

6. Re-repair application technique.

Starting with Step 1 of the procedure apply as original repair.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P4058-8A

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Loctite Retaining Compound No. 75-21

Equipment Required

None

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

   Wipe area of repair with trichloroethylene on clean Kim-wipe to remove all grease and foreign matter.

2. Safety precautions.

   Avoid contact with eyes. Flush with water immediately if contacted.

3. Application of repair (Technique).

   Apply thin layer from plastic nozzle to repair area extending 1/4 inch minimum from hole edges. Allow one hour to harden.

4. Post-repair cleaning, précautions, checks, etc.

   Check for bleed through into holes.

5. Re-repair preparation of unsuccessful repair area.

Scrape off loose repair material

6. Re-repair application technique.

Starting with Step 1, follow the procedure for original repair.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P 4058-9A

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Dow Corning 93-500 Encapsulant (2 part)

Equipment Required

Mixing Pot

Spatula

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

Wipe metal repair area with acetone using clean Kim-wipe to remove grease and foreign matter.

2. Safety precautions.

Neither the curing agent nor the encapsulant contain solvents. An extremely low level of volitiles is contained; avoid contamination.

3. Application of repair (Technique).

Thoroughly mix 10 parts of curing agent with 100 parts encapsulant (by weight). Do not entrain air. Pot life is one hour at room temperature. Spread a thin (approximately 1/16 inch thick) layer over repair area 1/4 inch (minimum) edge distance from hole. Allow one hour to cure.

4. Post-repair cleaning, precautions, checks, etc.

Check to be sure mixture has not bled through hole.

5. Re-repair preparation of unsuccessful repair area.

Remove any contamination.

6. Re-repair application technique.

Starting with Step 1, follow same procedure as original repair.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P4058-10B

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Sealstix cement (Dekhotinsky cement)

Equipment Required

Heat Gun (Hot air blower)

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

Wipe repair area with acetone on clean Kimwipe to remove all grease and foreign matter.

2. Safety precautions.

3. Application of repair (Technique).

Using heat gun raise the metal temperature of the repair area to 290°F to 350°F. Press the stick of cement onto the repair area and spread an even layer, melting cement at least 1/2 inch from edges of hole.

4. Post-repair cleaning, precautions, checks, etc.

None

5. Re-repair preparation of unsuccessful repair area.

Flake off old cement using dull knife blade or edge of spatula.

6. Re-repair application technique.

Starting with Step 1 of the procedure, continue as with original repair.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P4058-11B

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Indalloy Solders #1, 2, 3, 4, 5, 6, 7, 8, 9, 10 & 13
(Indium Corporation)

Equipment Required

Indalloy Flux #2
Tempil Sticks of 300°E, 350°F, 400°F, 450°F, 550°F & 600°F
Propane Torch or equivalent
CRES 18-8 wire brush

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

   Using clean CRES 18-8 wire brush, buff repair area 1/2 inch around hole edges. Do not wipe with non-metallic. Apply thin coating of Indalloy flux #2 only over area to be soldered with brush. Do not use excess flux.

2. Safety precautions.

   No Special Precautions

3. Application of repair (Technique).

   Using Tempil sticks to check temperature, heat repair area base metal with torch to the following schedule:

Indalloy No.	1, 8 & 13	2, 4 & 9	5	7	3 & 10	6
Temperature	300°F	350°F	400°F	450°F	550°F	600°F

   Using a wiping motion move the solder wire against the heated area to be repaired. A thin uniform coating should be applied to 1/4 inch away from hole edges. Solder should be applied quickly while metal is at melting heat.

4. Post-repair cleaning, précautions, checks, etc.

   Mix a hot (150°F to 190°F) solution of water and detergent cleanser (10% to 20% concentration). Scrub off flux using clean cotton rag dipped in the solution.

5. Re-repair preparation of unsuccessful repair area.

Same as Step 6

6. Re-repair application technique.

Starting with Step 1 of the procedure, proceed as with original repair.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number PA 4058-12A

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Lead Foil Tape, adhesive backed
(3M Company #420)

Equipment Required

None

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

   Wipe repair area with Acetone using clean Kimwipe. Remove all grease and foreign matter.

2. Safety precautions.

   No Special Requirements

3. Application of repair (Technique).

   Cut tape into shape so that 1/4 inch minimum edge distance will be allowed around hole. Do not touch adhesive backing or otherwise allow it to be contaminated. Press in place over hole smoothing any wrinkles out completely.

4. Post-repair cleaning, precautions, checks, etc.

   Check visually to insure 100% contact of entire patch surface with metal.

5. Re-repair preparation of unsuccessful repair area.

Peel entire foil patch off of metal surface and discard.

Do not re-use old patch.

6. Re-repair application technique.

Starting Step 1 of the procedure, proceed as with original repair.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P 4058-13A

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Duxseal, Nodrseal, Albaseal or Volseal
(Johns-Manville)

Equipment Required

None

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

   Wipe repair area with acetone using clean Kim-wipe. Remove all grease and foreign matter.

2. Safety precautions.

   NO SPECIAL PRECAUTIONS.

3. Application of repair (Technique).

   Pinch off small portion of repair material and roll into ball approximately 1/4 inch in diameter. .Press ball onto hole and flatten to form 1/16 inch thick disc with 1/4 inch minimum edge distance from hole edges. Feather out the edges of repair material to form smooth transition with no lumps or creases.

4. Post-repair cleaning, precautions, checks, etc.

   Check for porosity in repair material.

5. Re-repair preparation of unsuccessful repair area.

Remove entire amount of repair material originally applied.

6. Re-repair application technique.

Starting with step 1 of the procedure proceed as with original repair.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P 4058-14C

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Silvalloy #35 and #45 Silver solder wire

.032 inch diameter

Equipment Required

Propane torch or Oxy-acetylene equipment

CRES 18-8 wire brush.

"Black Flux" for brazing

Nitric Acid

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

   Using clean, dry CRES 18-8 wire brush, buff repair area to bright finish. Apply black flux generously over entire repair area.

2. Safety precautions.

   Provide good ventilation, brazing wire contains cadmium.

3. Application of repair (Technique).

   Holding end of brazing wire near base metal, heat both with torch until wire flows onto base metal. Do not heat base metal higher than necessary. Prolonged heating should be avoided. Make repair as quickly as is convenient. Edge distance from hole to edge of overlapping braze filler when finish should be 1/16 inch to 1/8 inch. Avoid excess filler. Use wet rag as quench to cool quickly after application.

4. Post-repair cleaning, precautions, checks, etc.

   Wipe off flux with water on clean rag. Wire brush to bright finish. Using 50% (by volume) nitric acid in water solution, swab repair area thoroughly. Allow acid to remain for thirty minutes, re-swabbing as necessary. Rinse with de-ionized water spray. Check visually for porosity or gaps.

5. <u>Re-repair preparation of unsuccessful repair area.</u>

Same as Step 6.

6. <u>Re-repair application technique.</u>

Starting with Step 1 of the procedure, proceed as with original repair.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P 4058-15D

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Type 300 series CRES welding rod (.020 inch diameter)

Equipment Required

150 amp (min.) DC Heliarc Welding power Supply with Argon Cup gas feed.

CRES 18-8 Wire Brush

Nitric Acid

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

   Using clean, dry CRES 18-8 wire brush, buff repair area to bright finish.

2. Safety precautions.

   Protect eyes from arc at all times.

3. Application of repair (Technique).

   Welding schedule:

   Amperage - 10 to 12 Voltage - 8 to 10

   Cup gas - Straight Argon, Flow - 15 ft^3/hr

   Polarity - Straight Electrode - 2% thoriated tungsten

   Procedure - Strike arc with electrode very close to hole. Simply push the filler rod in one quick strike on the hole and shut down the arc. Place wet rag over repaired area to quench quickly.

4. Post-repair cleaning, precautions, checks, etc.

   Wire brush repair to bright finish. Using 50% (by volume) nitric acid in water solution, swab area thoroughly. Allow acid to remain for thirty minutes, re-swabbing as necessary. Rinse with de-ionized water spray. Check visually for hole coverage.

5. Re-repair preparation of unsuccessful repair area.

Same as Step 6.

6. Re-repair application technique.

Starting with Step 1 of the procedure, proceed as with original repair.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P4058-18B

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Soft Solder 60% tin/40% lead

ASTM Class 60A (374°F Liquidus Temp.)

Equipment Required

Propane torch or equivalent

LLoyd's Stainless Steel Soldering Flux

CRES Type 18-8 wire brush

Tempil Stick(400°F)

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

Using clean CRES 18-8 wire brush, buff repair area 1/2 inch around hole edges. Do not wipe with non-metallic. Apply thin coating of flux with brush to repair area. Do not use excess flux.

2. Safety precautions.

Flux contains muriatic acid. Keep off skin, do not breathe fumes. Flush water over any contact area. Call doctor if eyes are contaminated.

3. Application of repair (Technique).

Using Tempil Stick to determine temperature, heat repair area base metal to 400°F. While maintaining temperature, press solder wire end onto repair area and form a thin even coating of solder with a wiping movement. Allow to cool at room temperature.

4. Post-repair cleaning, precautions, checks, etc.

Inspect solder visually for bright, clean appearance. If dull and grain-like in appearance, then re-melt and start over with Step 1 above.

5. Re-repair preparation of unsuccessful repair area.

Heat solder with torch to melting temperature taking care not to overheat excessively. Wipe melting solder away with CRES 18-8 wire brush.

6. Re-repair application technique.

Starting with Step 1 of the procedure, continue as with original repair.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P4058-19A

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Teflon FEP Adhesive back film .002 inch thick
(Cadillac Plastics Stock No. CT-599-AA)

Equipment Required

No Special Equipment.

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

   Wipe repair area with acetone on clean Kim-wipe to remove all grease and foreign matter.

2. Safety precautions.

   No special precautions.

3. Application of repair (Technique).

   Cut square of adhesive backed sheet sized to allow at least 1/2 inch edge distance around hole edges. Peel off paper backing and press firmly in place over hole. Smooth out any wrinkles completely.

4. Post-repair cleaning, precautions, checks, etc.

5. <u>Re-repair preparation of unsuccessful repair area.</u>

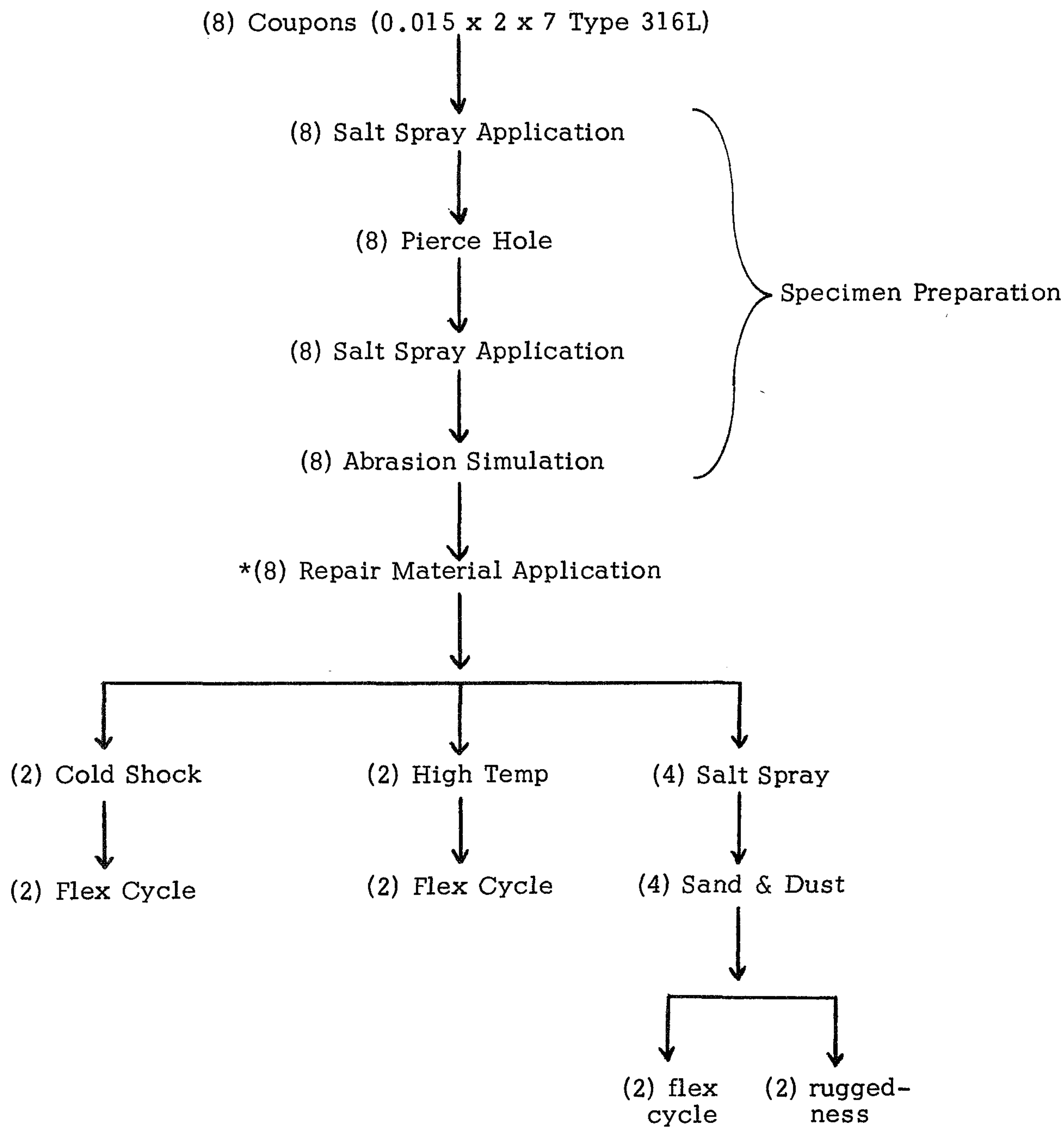
Peel off old patch material.

6. <u>Re-repair application technique.</u>

Starting with Step 1 of procedure continue as with new repair.

3.8.2.5 Tests Performed - Materials Evaluation

The first of the two stage testing program consisted of various environmental and functional tests as shown in their proper sequence on the Test Flow Chart on the following page. The specimen preparation and testing performed is given immediately following this flow chart. The test results and supporting data follow the test description section.



*After repair material application and after each test, a mass spectrometer Helium leak test will be performed.

Figure 36. Test Flow Chart

3.8.2.5.1 Specimen Preparation

Test specimens were treated prior to repair and test to simulate, as nearly as possible, environmental conditions of installation at Launch Complex 39. This was accomplished by the following steps:

Salt Spray

Purpose

The specimen was exposed to a salt atmosphere to simulate one (1) year of installation in its service environment.

Conditions

The test was conducted in accordance with Section 17 of KSC-STD-164D, and installed in the Salt Fog Test Set-up as shown on Page No. 149.

Prior to installation in the test chamber, the test item was visually inspected for corrosion, dirt and oily films. Location and extent of corrosion was recorded. Dirt and oily films were removed. The test item was installed in the test chamber in accordance with Paragraph 4.4.1 of KSC-STD-164D.

After 240 ± 2 hours of exposure in a salt fog of 5% salt and 95% water at 95 $^{+2}_{-4}$ oF, the test item was allowed to stand until thoroughly dry.

Induced Leakage

Purpose

The specimen was pierced with a hole .016 inch in diameter to simulate typical in-service damage.

Salt Spray

Purpose

The specimen was then exposed to a salt fog atmosphere to simulate exposure to in-service conditions after damage.

Conditions

Test conditions were in accordance with Paragraph 4.4.1 except the exposure duration was 120 ± 1 hour.

Abrasion Simulation

Purpose

The specimen was abraded to simulate metal to metal contact such as braid rubbing against the convolutions of a flex line.

Conditions

The specimen was abraded by making three (3) hard passes over the pierced area using a stiff wire brush of type 403 CRES.

Repair Material Application

Test specimen was repaired using the materials and techniques in accordance with the applicable repair procedure. A separate procedure was used for each repair material.

For each repair material, eight (8) test specimens were prepared, each with identical material and identical application technique.

3.8.2.5.2 Leakage Test

Prior to the first environmental test and after each environmental test, each specimen was leak tested using a helium mass spectrometer having a sensitivity of 1×10^{-10} cc/sec of He. Any detectable leakage was noted and that specimen was failed and the leak rate recorded. If leak rate was too high for mass spectrometer to read, this was so indicated on the data sheet.

3.8.2.5.3 Cold Shock Test

Purpose

The cold shock test was conducted to determine if the specimen would remain leak proof after subjection to cryogenic temperatures and subsequent flexure.

Test Conditions

The entire specimen was immersed in LN_2 and allowed to return to ambient. The specimen was then flexed through ten (10) cycles as described in Paragraph 3.8.2.5.7 except for the number of cycles.

Required Data

The specimens repair procedure number and number of flexure cycles was reported. Leak test and leak rate were recorded.

3.8.2.5.4 High Temperature Test

Purpose

The high temperature test was conducted to evaluate the test specimen under the most severe simulated high temperature conditions, that of its expected proximity to the blast of a launch vehicle during lift-off.

Test Conditions

A flame source having the minimum capability of 1400 ± 100°F was mounted in a fixed position as shown in High Temperature Test Set-up, Page 148. The distance from the flame at which the temperature of 1400 ± 100°F was attained was determined and marked. The test specimen was then exposed to the flame at this point for a period of ten (10) seconds.

Required Data

When the specimen was returned to room ambient conditions, it was visually inspected. Visible defects as the result of the test were recorded. Specimen repair procedure number was recorded. Leakage test and leak rate were recorded.

3.8.2.5.5 Salt Spray

Purpose

The salt fog test was performed to determine the resistance of the test specimen to a salt fog atmosphere.

Test Conditions

The test was conducted in accordance with Section 17 of KSC-STD 164D, and installed in the Salt Fog Test Set-up as shown on page 149.

Prior to installation in the test chamber, the test specimen was visually inspected for corrosion, dirt and oily films. Location and extent of corrosion was recorded. Dirt and oily film were removed. The test specimen was installed in the test chamber in accordance with Paragraph 4.4.1 of KSC-STD-164D.

After 240 ± 2 hours of exposure in a salt fog of 5% and 95% water at $95 ^{+2}_{-4}$ oF, the test specimen was allowed to stand until thoroughly dry.

3.8.2.5.6 Sand and Dust Test

Purpose

The sand and dust test was performed to determine the resistance of the test specimen to blowing fine sand and dust particles.

Test Conditions

The test was conducted in accordance with Section 16 of KSC-STD-164D.

The specimen was placed in the Sand and Dust Test Set-up as shown on Page 150 in accordance with Paragraph 4.4.1 of KSC-STD-164D. The test item was exposed to a sand and dust environment with a sand to air ratio of 0.1 to 0.25 grams per cubic foot and with an air velocity of from 100 to 500 feet per minute. The test item was exposed to this environment for two (2) hours at 77 $\pm$ 2^{o}F. The temperature was then raised to 160 $\pm$ 2^{o}F under the same test conditions for two (2) hours. At the conclusion of the sand and dust test, the test specimen was returned to room ambient conditions.

Required Data

The test chamber ambient temperature was continuously recorded. The sand to air ratio was measured at the beginning and conclusion of the test and every two (2) hours during the test. The test specimen was visually inspected at completion of the test and defects as a result of the test recorded. Specimen repair procedure number was recorded. Leakage test and leak rate were recorded.

3.8.2.5.7 Flex Cycle Test

Purpose

The purpose of the Flex Cycle Test was to determine the effect of repeated cycling across the repaired area of the test specimen.

Test Conditions

The specimen was installed in the Flex Cycle Test Set-up (Page 188). With one end of the specimen in a fixed position, the specimen was moved so that the flexure occurred across the repaired area. One cycle consisted of the free end being moved on inch on both sides of nominal. One hundred cycles were induced, a leak test conducted, another 200 cycles, leak test, another 500 cycles and leak test.

Required Data

The specimens repair procedure number and number of flexure cycles were recorded. Leakage test and leak rate were recorded.

3.8.2.5.8 Ruggedness Test

Purpose

To determine if the specimen would withstand rough handling such as might occur during shipment and installation.

Test Conditions

The specimen was installed in the Ruggedness Test Set-up as shown on Page 151 so that the striking anvil would strike the repaired area. The striking anvil was dropped from a height sufficient to apply a force of 110 lbs. on the repaired area.

Required Data

The specimen repair procedure number and the visually detectable effects of the strike were recorded. Leakage tests and leak rate were recorded.

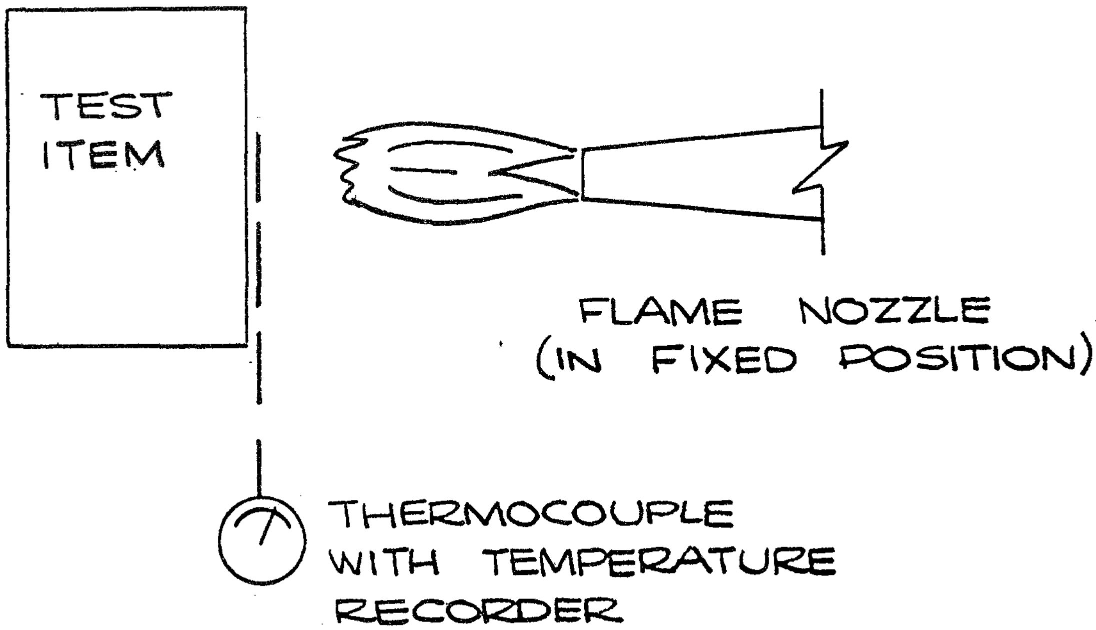


Figure 37. High Test Temperature Test Set-up

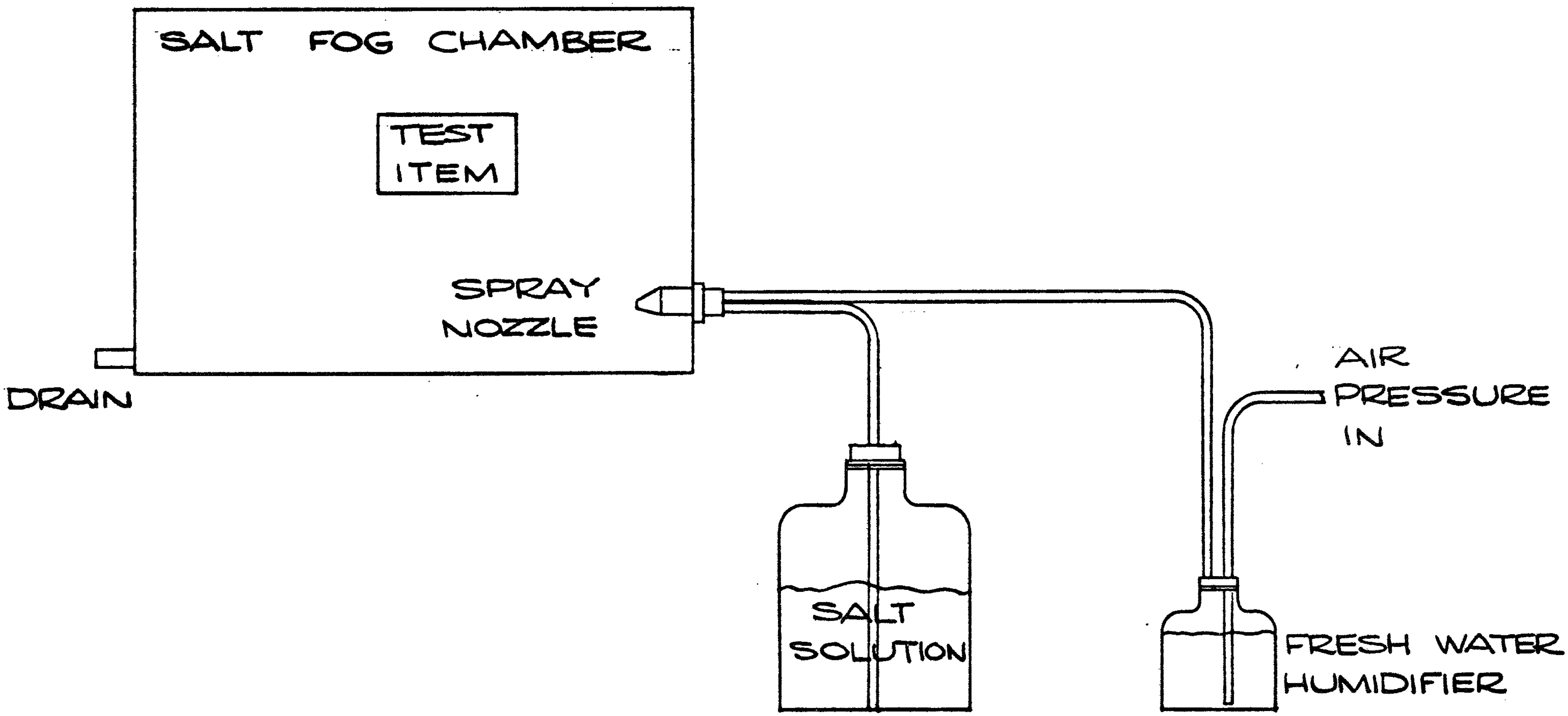


Figure 38. Salt Fog Test Set-up

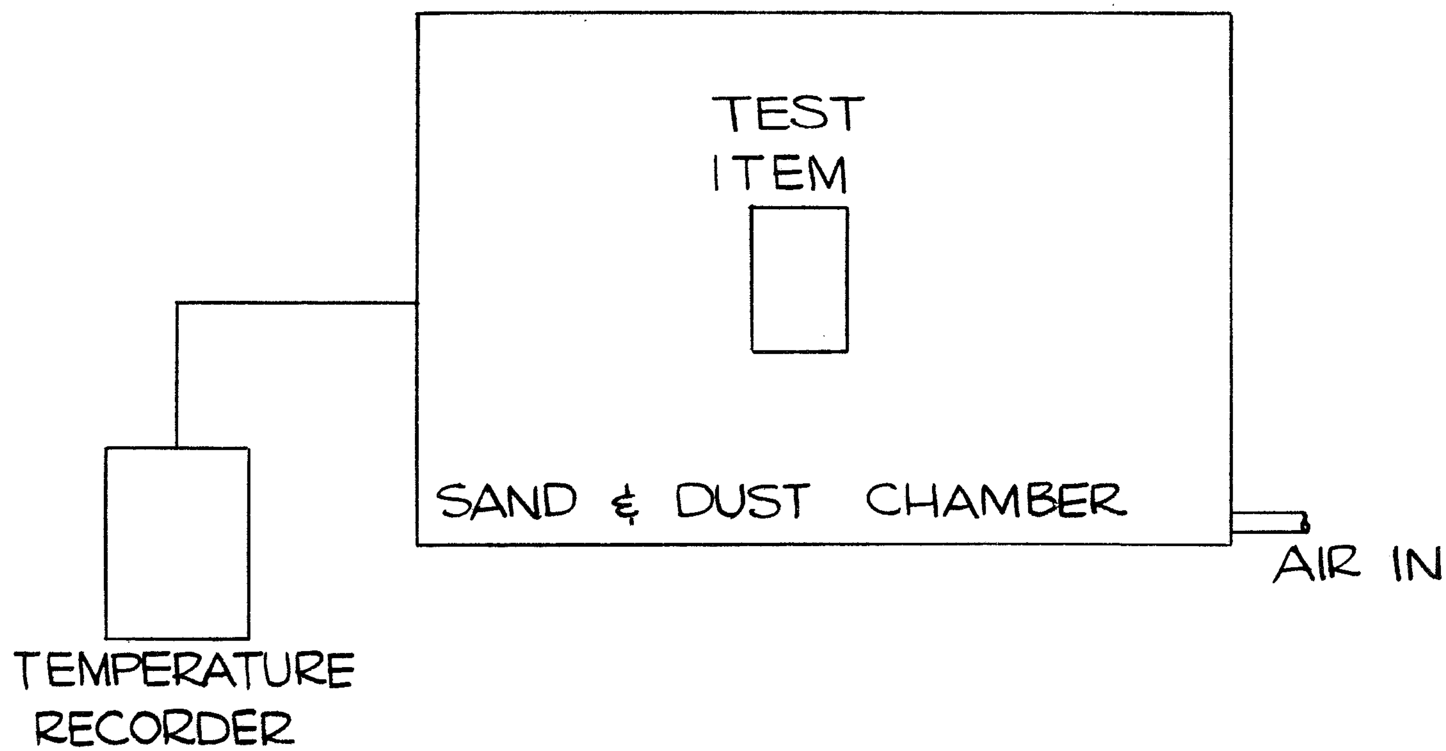


Figure 39. Sand & Dust Test Set-up

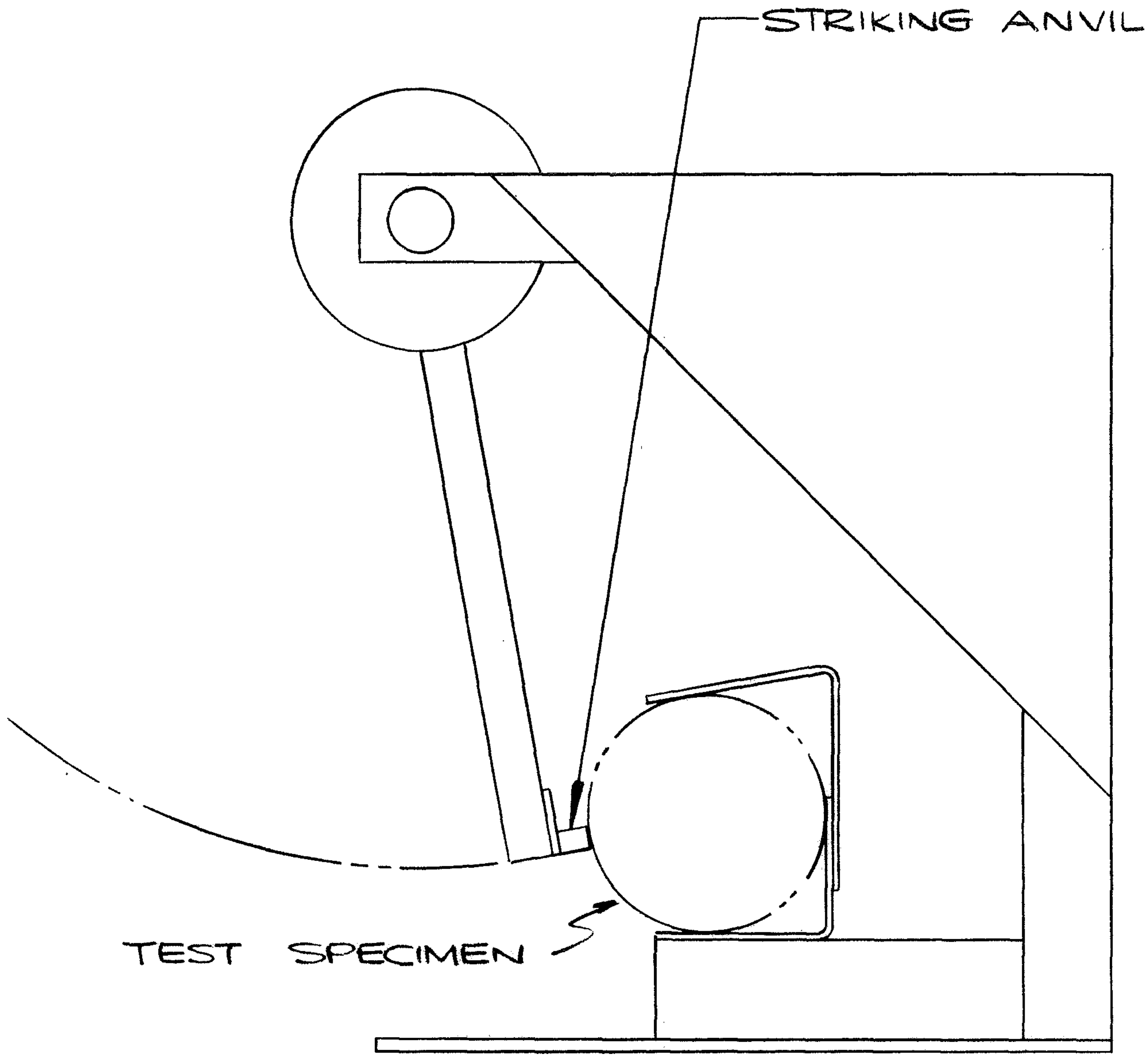


Figure 40. Ruggedness Test Set-up

3.8.2.6 Test Results - Material Evaluation, Data Sheets and Figures

Data sheets and supporting photos reflecting the results of the foregoing testing are given on the following pages of this section.

It should be noted that all tests accomplished on a given repair specimen are included in each test data sheet. The pass and fail column of the data sheet indicates the total number of specimens subjected to any given test. Following the Leak Repair Material Evaluation Data Sheets, the test results are summarized by test. Each of these individual test summary sheets presents the results of all material tested for a given type of test. Refer to the Test Flow Chart on Page 142 for the planned number of specimens to be subjected to each test.

LEAK REPAIR MATERIAL EVALUATION

TEST DATA SHEET

Material Tested Dow Corning #732 RTV (Silicone Rubber)

Repair Procedure P4058-1A

Test Procedure 8-480093

TEST RESULTS

TEST	Date	Pass	Fail	Leakage not measurable	Leakage rate
Salt Spray		(4)			
Sand and Dust		(3)	(1)	#	
Flexure		(4)			
Cold Shock		(2)			
High Temperature		(1)	(1)		2 X 10^{-8} cc/sec
Ruggedness		(1)			

Comments: One specimen failed sand & dust, one specimen failed high temperature. Failures might be caused by uneven thickness of application. With more care in application and greater thickness, material is recommended for further testing.

Test Technician [signature]

Test Engineer [signature]

LEAK REPAIR MATERIAL EVALUATION

TEST DATA SHEET

Material Tested Narmco Cryogenic Cement (two part)

#7111 Curing Agent, #3135 Resin

Repair Procedure P4058-2B

Test Procedure 8-480093

TEST RESULTS

TEST	Date	Pass	Fail	Leakage	
				not measurable	rate
Salt Spray		(2)	(2)		
Sand and Dust		(2)			
Flexure		(1)	(1)		
Cold Shock	*	(1)	(1)		3 $X10^{-9}$ cc/sec
High Temperature	*	(1)	(1)		1 X 10^{-7} cc/sec
Ruggedness			(2)	#	

Comments: * Only one specimen of each failed cold shock and high temperature. A testing error in over exposure to 1400°F probably caused high temperature test failure. Material is brittle after curing however. This caused ruggedness test failure. Not recommended for further testing.

Test Technician [signature]

Test Engineer [signature]

LEAK REPAIR MATERIAL EVALUATION

TEST DATA SHEET

Material Tested General Electric #RTV 102 (Silicone rubber)

Repair Procedure P4058-3A

Test Procedure 8-480093

TEST RESULTS

TEST	Date	Pass	Fail	Leakage	
				not measurable	rate
Salt Spray		(2)	(2)		
Sand and Dust			(2)		
Flexure					
Cold Shock			(2)		
High Temperature			(2)		
Ruggedness					

Comments: Thick, even coating easy to apply, however, early test failures of all specimens indicate recommendation of no further testing. Poor adhesion was apparent cause of failures.

Test Technician [signature]

Test Engineer K Kittle

LEAK REPAIR MATERIAL EVALUATION

TEST DATA SHEET

Material Tested Loctite #54-52, #2508, #69-52, #7521 and "Plastic Gasket"

Repair Procedure PA4058-4B, -5B, -6A, -7A and -8A

Test Procedure 8-480093

TEST RESULTS

TEST	Date	Pass	Fail *	Leakage not measurable	Leakage rate
Salt Spray					
Sand and Dust					
Flexure					
Cold Shock					
High Temperature					
Ruggedness					

Comments: *None of these materials passed the first leak test. Leakage was too great to be on scale on the mass spectrometer. None are recommended for further testing. Failures are due either to material not curing or their inherent permeability.

Test Technician [signature]

Test Engineer K Kimble

LEAK REPAIR MATERIAL EVALUATION

TEST DATA SHEET

Material Tested Dow Corning #93-500 Encapsulant

Repair Procedure P4058-9A

Test Procedure 8-480093

TEST RESULTS

TEST	Date	Pass	Fail *	Leakage not measurable	Leakage rate
Salt Spray					
Sand and Dust					
Flexure					
Cold Shock					
High Temperature					
Ruggedness					

Comments: *All specimens failed initial leak test. Material apparently porous. Not recommended for further testing.

Test Technician [signature]

Test Engineer K Kimble

LEAK REPAIR MATERIAL EVALUATION

TEST DATA SHEET

Material Tested Sealstix Cement (Dekhotinsky Type)

Repair Procedure P4058-10B

Test Procedure 8-480093

TEST RESULTS

TEST	Date	Pass	Fail	Leakage	
				not measurable	rate
Salt Spray		(4)			
Sand and Dust		(4)			
Flexure			(2)		
Cold Shock			(2)		
High Temperature			(2)		
Ruggedness	*				

Comments: *Material is brittle after curing. Tends to bleed through holes when first applied. Not recommended for further testing.

Test Technician [signature]

Test Engineer [signature]

LEAK REPAIR MATERIAL EVALUATION

TEST DATA SHEET

Material Tested Indalloy (Indium Corporation)

#1, 2, 3, 4, 5, 6, 7, 8, 9, 10 & 13

Repair Procedure P4058-11B

Test Procedure 8-480093

TEST RESULTS

TEST	Date	Pass	Fail	Leakage	
				not measurable	rate
Salt Spray			see comments	#	
Sand and Dust			"	#	
Flexure			"	#	
Cold Shock			"	#	
High Temperature			"	#	
Ruggedness			"	#	

Comments: #3, 9, 10, 4 and 13 were extremely difficult to apply due to poor wetting quality and leaked at first leak test. #1, 2 and 5 failed salt spray, high temperature and sand & dust tests. #6, 7 and 8 failed cold shock, high temperature, flex cycle and ruggedness. None recommended for further testing.

Test Technician [signature]

Test Engineer [signature]

LEAK REPAIR MATERIAL EVALUATION

TEST DATA SHEET

Material Tested Leak Foil Tape - 3M Company #420

Repair Procedure PA 4058-12A

Test Procedure 8-480093

TEST RESULTS

TEST	Date	Pass	Fail	Leakage not measurable	Leakage rate
Salt Spray		(4)			
Sand and Dust		(4)			
Flexure			(4)	#	
Cold Shock			(2)	#	
High Temperature			(2)	#	
Ruggedness					

Comments: Material not recommended for further testing. It is Highly dependent on careful application as to sealing ability. It tends to wrinkle and adhesion is variable from one application to the next.

Test Technician

Test Engineer

LEAK REPAIR MATERIAL EVALUATION

TEST DATA SHEET

Material Tested ____ Alboseal (Johns-Manville) ____

Repair Procedure ____ P4058-13A ____

Test Procedure ____ 8-480093 ____

TEST RESULTS

TEST	Date	Pass	Fail	Leakage not measurable	Leakage rate
Salt Spray					
Sand and Dust					
Flexure					
Cold Shock					
High Temperature					
Ruggedness					

Comments: Did not pass initial leak test after application. . Poor adhesion to CRES, low strength and gas permeability caused failures.

Test Technician ____

Test Engineer K Kuhl ____

LEAK REPAIR MATERIAL EVALUATION

TEST DATA SHEET

Material Tested Nodrseal (Johns-Manville)

Repair Procedure P 4058-13A

Test Procedure 8-480093

TEST RESULTS

TEST	Date	Pass	Fail	Leakage not measurable	Leakage rate
Salt Spray		(2)	(2)	#	
Sand and Dust		(2)	(2)	#	
Flexure	*				
Cold Shock			(2)	#	
High Temperature			(2)	#	
Ruggedness	*				

Comments: Did not run flexure or ruggedness. Not recommended as repair material. Material is apparently highly gas permeable and adhesion is poor.

Test Technician [signature]

Test Engineer K Kuh[signature]

LEAK REPAIR MATERIAL EVALUATION

TEST DATA SHEET

Material Tested Volseal (Johns - Manville)

Repair Procedure P4058-13A

Test Procedure 8-480093

TEST RESULTS

TEST	Date	Pass	Fail	Leakage	
				not measurable	rate
Salt Spray		(4)			
Sand and Dust		(4)			
Flexure		(5)			
Cold Shock		(1)			
High Temperature		(2)			
Ruggedness		(2)			

Comments: One specimen of eight failed initial leak test. Poor application was probable cause. Material is recommended for further testing. Adhesion tends to get much better with time.

Test Technician [signature]

Test Engineer K Kimbo

LEAK REPAIR MATERIAL EVALUATION

TEST DATA SHEET

Material Tested: Duxseal (Johns-Manville)

Repair Procedure: P4058-13A

Test Procedure: 8-480093

TEST RESULTS

TEST	Date	Pass	Fail	Leakage	
				not measurable	rate
Salt Spray		(4)			
Sand and Dust			(2)	#	
Flexure		(2)			
Cold Shock			(2)	#	
High Temperature			(2)	#	
Ruggedness	*				

Comments: *Did not ruggedness test. Previous test failures indicated poor repair material. Not recommended for further testing or for use as a repair material. Poor adhesion and low strength caused failures.

Test Technician [signature]

Test Engineer K Kimble

LEAK REPAIR MATERIAL EVALUATION

TEST DATA SHEET

Material Tested Silvalloy #35 and #45 Silver Solder

(.032 dia. wire)

Repair Procedure P4058-14C

Test Procedure 8-480093

TEST RESULTS

TEST	Date	Pass	Fail	Leakage	
				not measurable	rate
Salt Spray		(4)			
Sand and Dust		(4)			
Flexure		(6)			
Cold Shock		(2)			
High Temperature		(2)			
Ruggedness		(2)			

Comments: Removal of flux was difficult. Some corrosion appeared to take place and with age could cause problems. However, no failures occurred. Further testing is recommended for #45 since it showed least tendency to corrode.

Test Technician [signature]

Test Engineer K Kn[signature]

LEAK REPAIR MATERIAL EVALUATION

TEST DATA SHEET

Material Tested Type 300 Series CRES TIG weld with .020 diameter weld rod

Repair Procedure P4058-15D

Test Procedure 8-480093

TEST RESULTS

TEST	Date	Pass	Fail	Leakage not measurable	Leakage rate
Salt Spray		(4)			
Sand and Dust		(3)	(1)	#	
Flexure		(5)			
Cold Shock		(2)			
High Temperature		(2)			
Ruggedness		(2)			

Comments: Easily applied to .016 inch thick coupons, reason for the single failure in sand and dust is unknown. Recommended for further testing.

Test Technician [signature]

Test Engineer K Kimball

LEAK REPAIR MATERIAL EVALUATION

TEST DATA SHEET

Material Tested: Soft Solder - 60% tin / 40% lead
ASTM Class 60A

Repair Procedure: P4058-18B

Test Procedure: 8-480093

TEST RESULTS

TEST	Date	Pass	Fail	Leakage: not measurable	Leakage: rate
Salt Spray		(4)			
Sand and Dust		(4)			
Flexure		(6)			
Cold Shock		(2)			
High Temperature		(2)			
Ruggedness		(2)			

Comments: Quick, easy application, no failures. Recommended for further testing.

Test Technician [illegible]

Test Engineer [illegible]

LEAK REPAIR MATERIAL EVALUATION

TEST DATA SHEET

Material Tested Teflon FEP Adhesive backed film,

.002 inch thick. Cadillac Plastics #CT-599-AA

Repair Procedure P4058-19A

Test Procedure 8-480093

TEST RESULTS

TEST	Date	Pass	Fail (1)	Leakage not measurable	Leakage rate
Salt Spray					
Sand and Dust					
Flexure					
Cold Shock					
High Temperature					
Ruggedness					

Comments: All specimens failed first leak test. Adhesive backing did not appear to stick uniformly. Not recommended for further testing.

Test Technician [signature]

Test Engineer [signature]

LEAK REPAIR MATERIALS EVALUATION

TEST DATA SHEET

SALT SPRAY TEST

MATERIAL	TEST RESULTS	COMMENTS
Dow-Corning #732	(4) Pass, no failures	
Narmco Cement	(2) Pass, (2) Fail	Leak Rate off scale on mass spec.
G.E. RTV 102	(2) Pass, (2) Fail	Leak Rate off scale on mass spec.
Loctite (all)	None passed initial leak	test after application
Dow Corning #93-500	None passed initial leak	test after application
Dekhotinsky Cement	(4) Pass, no failures	
Indium #1, #2 and #5	(2) Pass, (2) Fail	Leak Rate off scale on mass spec.
Indium #3, #9, #10, #4, #13	None passed initial leak	test after application
Indium #6, #7 and #8	(4) Pass, No Failures	
J-M Albaseal	None passed initial leak	test after application
J-M Nodrseal	(2) Pass, (2) Fail	Leak rate off scale on mass spec.
J-M Volseal	(4) Pass, No failures	
J-M Duxseal	(4) Pass, No Failures	
Silvalloy #35 and #45	(4) Pass, No Failures	Some corrosion observed
Lead Foil Tape	(4) Pass, No failures	
Heliarc (TIG) welding	(4) Pass, No failures	
Soft Solder 60/40	(4) Pass, No failures	Traces of corrosion observed
Teflon Tape	None passed initial leak	test after application

LEAK REPAIR MATERIALS EVALUATION

TEST DATA SHEET

SAND AND DUST TEST

MATERIALS	TEST RESULTS	COMMENTS
Dow-Corning #732	(3) Pass, (1) Fail	Failure due to uneven application
Narmco Cement	(2) Pass, no failures	
G.E. RTV102	None passed, (2) failed	Leak rate off scale on mass spec.
Loctite (all)	None passed initial leak test after application.	
Dow Corning #93-500	None passed initial leak test after application.	
Dekhotinsky Cement	(4) Pass, no failures	
Indium #1, #2 and #5	None passed, (2) Fail	
Indium #3, #9, #10, #4, and #13	None passed initial leak test after application.	
Indium #6, #7 and #8	(4) Pass, no failures	
J-MAlbaseal	None passed initial leak test after application.	
J-M Nodrseal	(2) Pass, (2) Fail	Leak rate off scale on mass spec.
J-M Volseal	(4) pass, no failures	
J-M Duxseal	(2) pass, (2) failed	Leak rate off scale on mass spec.
Silvalloy #35 and #45	(4) pass, no failures	
Lead Foil Tape	(4) pass, no failures	
Heliarc (TIG) Welding	(3) pass, (1) failure	Cause of failure not known.
Soft Solder 60/40	(4) pass, no failures	
Teflon Tape	None passed initial leak test after application.	

LEAK REPAIR MATERIALS EVALUATION

TEST DATA SHEET

COLD SHOCK TEST

MATERIAL	TEST RESULTS	COMMENTS
Dow-Corning #732	(2) Pass, No failures	
Narmco Cement	(1) Pass, (1) Fail	3 X 10^{-9} cc/sec. leak rate on failure
G.E. RTV102	None passed, (2) failed	Leak rate off scale on mass spec.
Loctite (all)	None passed initial leak test after application.	
Dow-Corning #93-500	None passed initial leak test after application.	
Dekhotinsky Cement	None passed (2) failed	Leak rate off scale on mass spec.
Indium #1, #2 and #5	None advanced to this stage of testing	
Indium #3, #9, #10, #4 and #13	None passed initial leak test after application	
Indium #6, #7 and #8	None passed (2) failed	Leak rate off scale on mass spec.
J-M Albaseal	None passed initial leak test after application	
J-M Nodrseal	None passed (2) Failed	Leak rate off scale on mass spec.
J-M Volseal	(1) pass, no failures	(1) specimen leaked after initial application.
J-M Duxseal	None passed, (2) failed	Leak rate off scale on mass spec.
Silvalloy #35 and #45	(2) passed, no failures	
Lead Foil Tape	None passed (2) failed	Leak rate off scale on mass spec.
Heliarc (TIG) Welding	(2) passed, no failures	
Soft Solder 60/40	(2) passed,no failures	
Teflon Tape	None passed initial leak test after application	

LEAK REPAIR MATERIALS EVALUATION

TEST DATA SHEET

HIGH TEMPERATURE TEST

MATERIAL	TEST RESULTS	COMMENTS
Dow-Corning #732	(1) Pass (1) Fail	2×10^{-8} cc/sec leak rate on failure
Narmco Cement	(1) Pass (1) Fail	1×10^{-7} cc/sec leak rate on failure
G.E. RTV102	None passed, (2) failed	Leak rate off scale on mass spec.
Loctite (all)	None passed initial leak test after application	
Dow-Corning #93-500	None passed initial leak test after application	
Dekhotinsky Cement	None passed (2) failed	Leak rate off scale on mass spec.
Indium #1, #2 and #5	None passed (2) failed	Leak rate off scale on mass spec.
Indium #3, #9, #10, #4 and #13	None passed initial leak test after application	
Indium #6, #7 and #8	None passed (2) Failed	Leak rate off scale on mass spec.
J-M Albaseal	None passed initial leak test after application	
J-M Nodrseal	None passed (2) failed	Leak rate off scale on mass spec.
J-M Volseal	(2) passed, no failures	
J-M Duxseal	None passed, (2) failed	Leak rate off scale on mass spec.
Silvalloy #35 #45	(2) passed, no failures	
Lead Foil Tape	None passed, (2) Failed	Leak rate off scale on mass spec.
Heliarc (TIG) Welding	(2) Passed, No failures	
Soft Solder 60/40	(2) passed, no failures	
Teflon Tape	None passed initial leak test after application	

LEAK REPAIR MATERIALS EVALUATION

TEST DATA SHEET

FLEX CYCLE TEST

MATERIALS	TEST RESULTS	COMMENTS
Dow-Corning #732	(4) Pass, no failures	
Narmco Cement	(1) Pass, (1) Fail	Leak rate off scale on mass spec.
G.E. RTV102	None advanced to this stage of testing	
Loctite (all)	None passed initial leak test after application	
Dow-Corning #93-500	None passed initial leak test after application	
Dekhotinsky Cement	None passed, 2 failed	Leak rate off scale on mass spec.
Indium #1, #2 and #5	None advanced to this stage of testing	
Indium #3, #9, #10, #4 and #13	None passed initial leak test after application	
Indium #6, #7 and #8	None passed (2) failed	Leak rate off scale on mass spec.
J-M Albaseal	None passed initial leak test after application	
J-M Nodrseal	None advanced to this stage of testing	
J-M Volseal	(5) pass, no failures	(1) specimen did not advance to this test.
J-M Duxseal	(2) pass, (2) fail	Leak rate off scale on mass spec.
Silvalloy #35 and #45	(6) pass, no failures	
Lead Foil Tape	None passed, (2) failed	
Heliarc (TIG) Welding	(5) passed, no failures	
Soft Solder 60/40	(6) pass, no failures	
Teflon Tape	None passed initial leak test after application	

LEAK REPAIR MATERIALS EVALUATION

TEST DATA SHEET

RUGGEDNESS TEST

MATERIALS	TEST RESULTS	COMMENTS
Dow-Corning #732	(1) Pass, No failures	
Narmco Cement	None passed, (2) failed	Leak rate off scale on mass spec.
GE RTV102	None advanced to this stage of testing	
Loctite (all)	None passed initial leak test after application.	
Dow-Corning #93-500	None passed initial leak test after application.	
Dekhotinsky Cement	None advanced to this stage of testing	
Indium #1, #2 and #5	None advanced to this stage of testing	
Indium #3, #9, #10,#4 and #13	None passed initial leak test after application	
Indium #6, #7 and #8	None passed (2) failed	Leak Rate off scale on mass spec
J-M Albaseal	None passed initial leak test after application	
J-M Nodrseal	None advanced to this stage of testing	
J-M Volseal	(2) passed, no failures	
J-M Duxseal	None advanced to this stage of testing	
Silvalloy #35 and #45	(2) passed, no failures	
Lead Foil Tape	None advanced to this stage of testing	
Heliarc (TIG) welding	(2) passed, no failures	
Soft Solder 60/40	(2) passed, no failure	
Teflon Tape	None passed initial leak test after application	

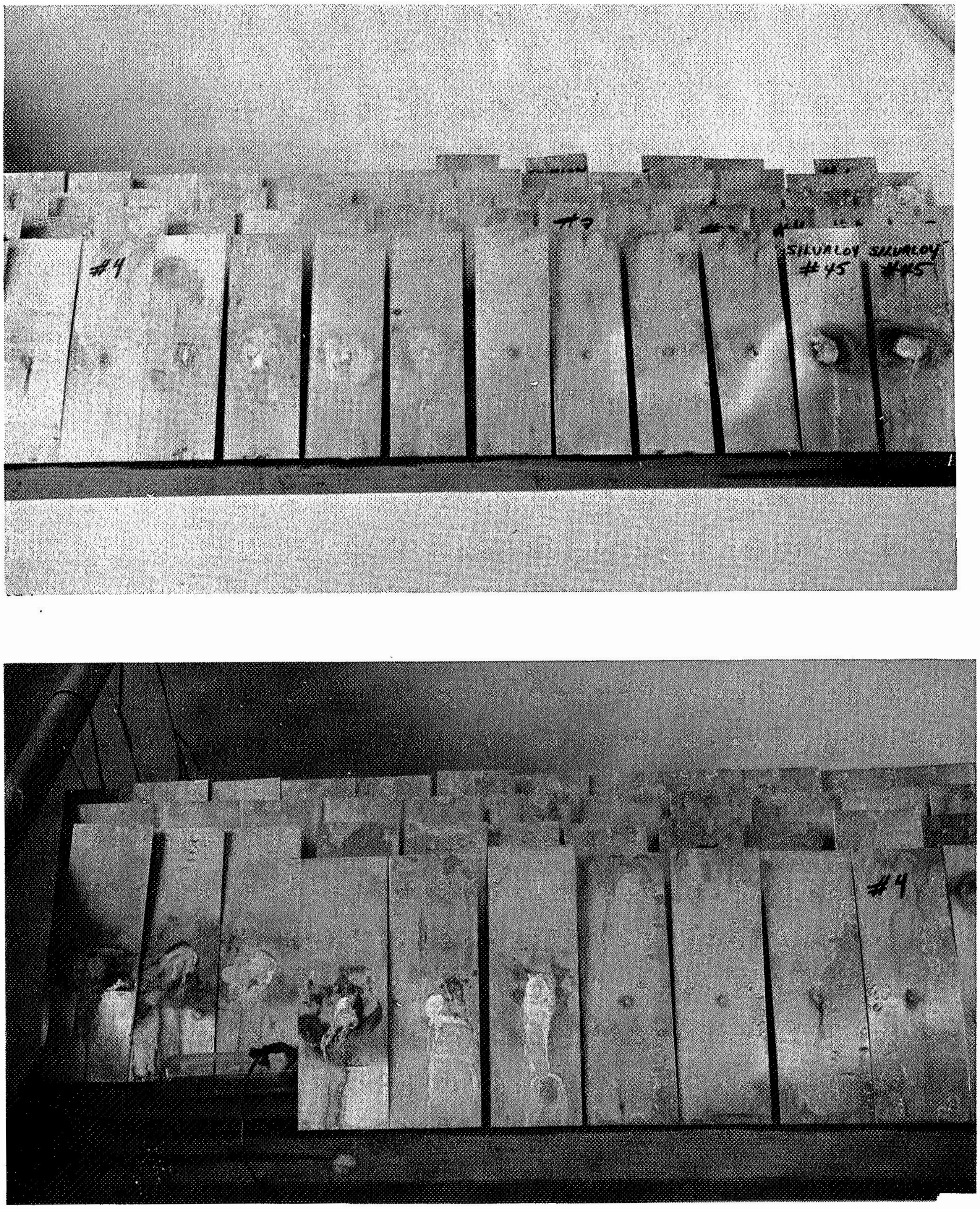


Figure 41. Repair Material Sample Coupons Salt Spray Test

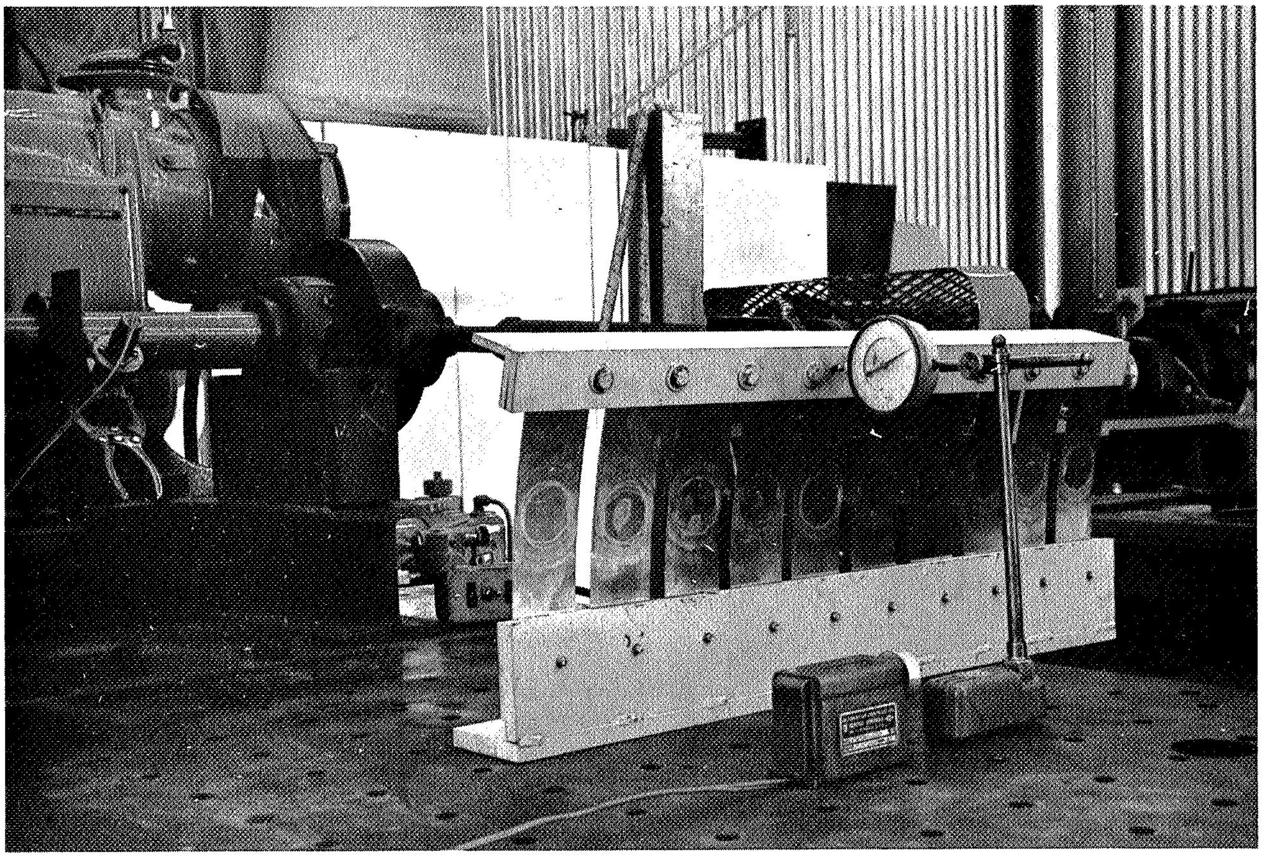


Figure 42. Repair Coupon Flexure Test in Progress

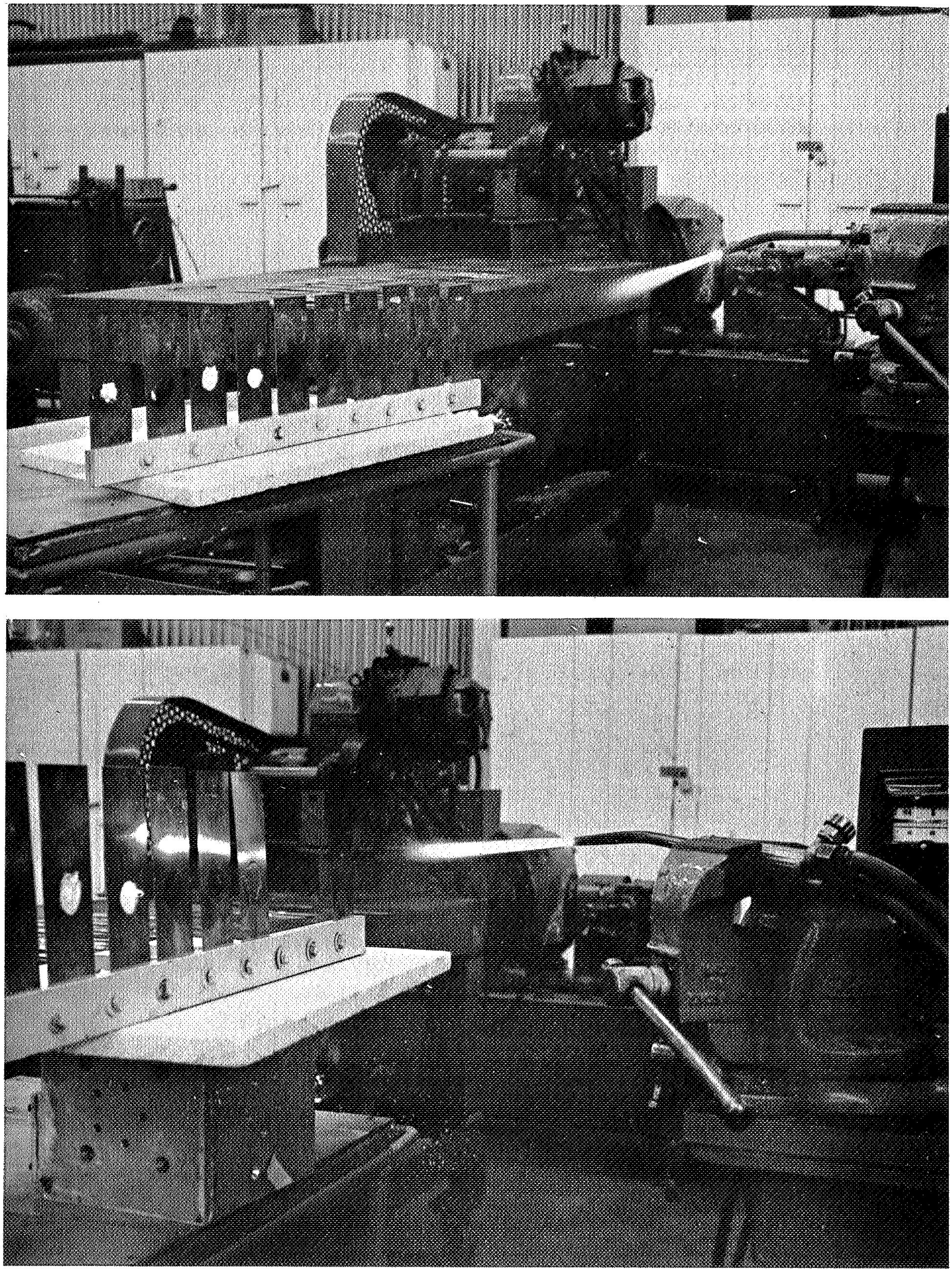


Figure 43. Repair Coupon High Temperature Test Set-up

3.8.2.7 Materials Evaluation Summary

All of the repair materials listed in Paragraph 3.8.2.3 were eliminated from consideration for further testing, except the following:

Dow Corning RTV #732
Johns-Manville "Volseal"
Silver Solder
Heliarc Welding
Soft Solder

The Loctite materials were too low viscosity and/or helium permeable. The Indium Solders did not generally have good wetting properties on the type 316L CRES bellows. The same general problems were found with most of the failures either the materials cured to a brittle hardness (such as the Dekhotinsky Cement) or did not adhere to the leak (such as the lead foil tape).

3.8.2.8 Tests Performed - Simulated Repair

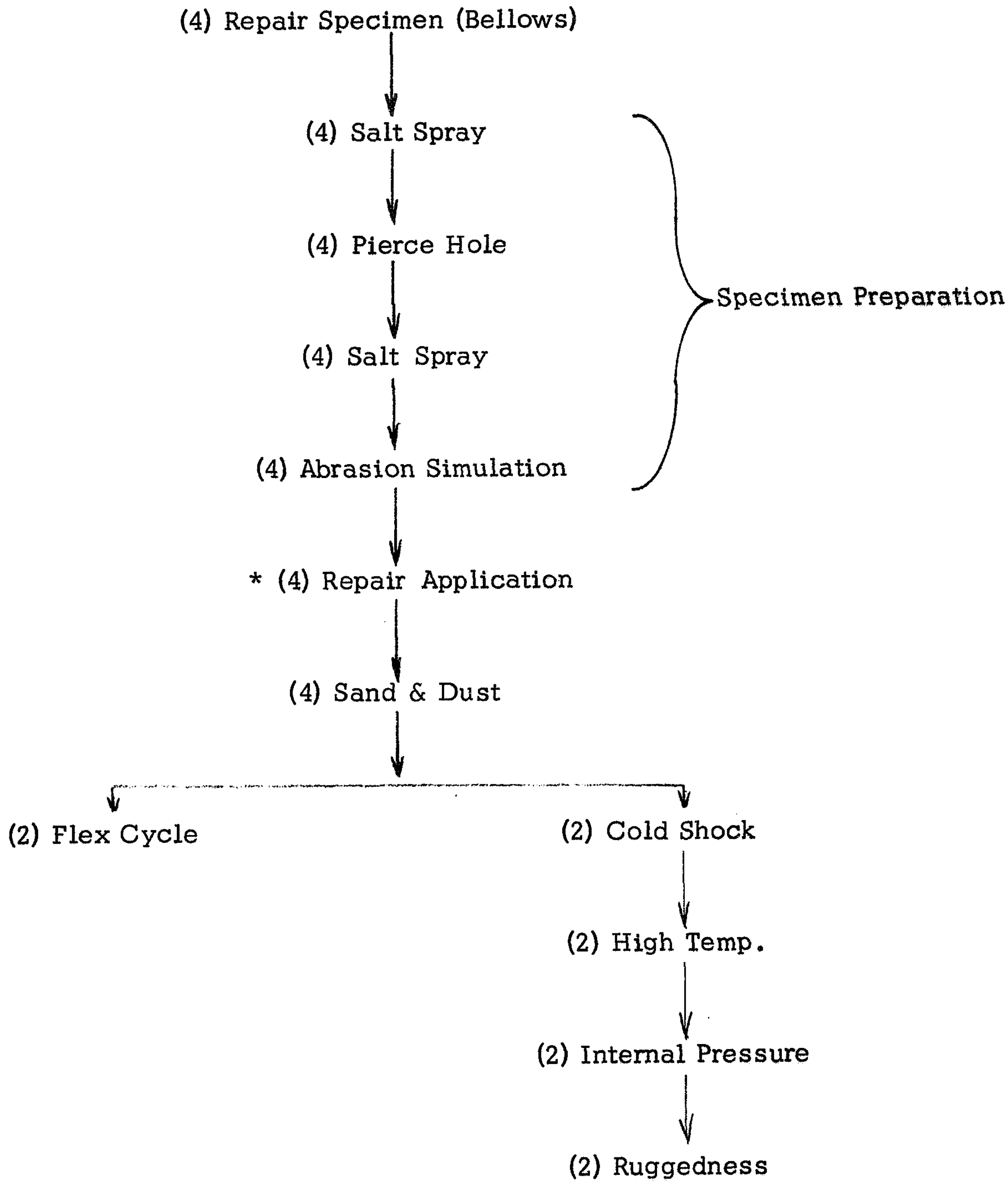
Based on the results of the Materials Evaluation testing as given in the preceeding documents, all but five of the materials were eliminated from consideration. The materials and their repair procedures which merited further testing were as follows:

P4058-1A Dow Corning RTV #732 (No heat)
P4058-13A Johns-Manville "Volseal" (No heat)
P4058-14C Silvalloy #45 Silver Solder (Moderate heat)
P4058-15D Heli-Arc TIG Weld (High heat)
P4058-18B Soft Solder 60/40 (Low heat)

The above Repair Procedures are given in Paragraph 3.8.2.9 and it should be noted that in some cases changes were made based on the Materials Evaluation Testing.

The Test Flow Chart on the following pages gives the sequence of testing for the Simulated Repair Test Procedure.

The tests performed are described following the flow chart. Test results and supporting data are given after the test of the procedure for testing.



*After repair material application and after each test a mass spectrometer He leak test will be performed.

Figure 44. Test Flow Chart

3.8.2.8.1 Specimen Preparation

Test specimens were treated prior to repair and test to simulate, as nearly as possible, environmental conditions of installation at Launch Complex 39. This was done by the following steps:

Salt Spray

Purpose

The specimen was exposed to a salt atmosphere to simulate one (1) year of installation in its service environment.

Conditions

The test was conducted in accordance with Section 17 of KSC-STD-164D, and installed in the Salt Fog Test Set-up as shown on Page 185.

Prior to installation in the test chamber, the test item was visually inspected for corrosion, dirt and oily films. Location and extent of corrosion was recorded. Dirt and oily films were removed. The test item was installed in the test chamber in accordance with Paragraph 4.4.1 of KSC-STD-164D.

After 240 ± 2 hours of exposure in a salt fog of 5% salt and 95% water at 95^{+2}_{-4}o F the test item was allowed to stand until thoroughly dry.

Induced Leakage

Purpose

The specimen was pierced with a hole .016 inch in diameter to simulate typical in-service damage.

Salt Spray

Purpose

The specimen was exposed to salt fog atmosphere to simulate exposure to in-service conditions after damage.

Conditions

Test conditions were in accordance with Paragraph 4.4.1 except the exposure duration was 120 ± 1 hour.

Abrasion Simulation

Purpose

The specimen was abraded to simulate metal to metal contact such as braid rubbing against the convolutions of a flex line.

Conditions

The specimen was abraded by making three (3) hard passes over the pierced area using a stiff wire brush of type 304 CRES.

Repair Material Application Procedure

Test specimens were repaired using the materials and techniques in accordance with the applicable repair procedure. A separate procedure was prepared for each repair material. These procedures are on Pages 217 thru 231. Each specimen was identified by repair procedure number. For each repair material, four (4) test specimens were prepared, each with identical material and identical application technique.

3.8.2.8.2 Leakage Test

Prior to the first environmental test and after each environmental test, each specimen was leak tested using a helium mass spectrometer having a sensitivity of 1×10^{-10} cc/sec of He. Any detectable leakage was recorded and that specimen failed.

Sand and Dust

Purpose

The sand and dust test was performed to determine the resistance of the test specimen to blowing fine sand and dust particles.

Test Conditions

The test was conducted in accordance with Section 16 of KSC-STD-164D.

The test specimen was placed in the test chamber as shown on Page 186 and in accordance with Paragraph 4.4.1 of KSC-STD-164D.

The test specimen was exposed to a sand and dust environment with a sand to air ratio of 0.1 to 0.25 grams per cubic foot and with an air velocity of from 100 to 500 feet per minute.

The test item was exposed to this environment for two (2) hours at 77 ± 2°F. The temperature was then raised to 160 ± 2°F under the same test conditions for two (2) hours. At the conclusion of the sand and dust test, the test specimen was returned to room ambient conditions.

Required Data

The test chamber ambient temperature was continuously recorded. The sand to air ratio was measured at the beginning and conclusion of the test and every two (2) hours during the test. The test specimen was visually inspected at completion of the test and defects as a result of the test recorded. The specimen repair procedure number was recorded, leakage test and leak rate recorded.

3.8.2.8.3 **Cold Shock Test**

Purpose

The cold shock test was conducted to determine if the specimen would remain leak proof after subjection to cryogenic temperature and flexures.

Test Conditions

The entire specimen was immersed in LN_2 and allowed to return to ambient. The specimen was then flexed through ten (10) cycles as described in Paragraph

Required Data

The specimens repair procedure number and number of flexure cycles, leak test and leak rate were recorded.

3.8.2.8.4 High Temperature Test

Purpose

The high temperature test was conducted to evaluate the test specimen under the most severe simulated high temperature conditions, that of its expected proximity to the blast of a launch vehicle during lift-off.

Test Conditions

A flame source having the minimum capability of 1400 ± 100°F was mounted in a fixed position. (See Page 187). The distance from the flame at which the temperature of 1400 ± 100°F was attained was determined and marked. The test specimen was then exposed to the flame at this point for a period of ten (10) seconds.

Required Data

When the test specimen was returned to room ambient conditions, it was visually inspected. Visible defects as the result of the test were recorded. Specimen repair procedure number and leak rate were recorded.

3.8.2.8.5 **Internal Pressure Test**

Purpose

To determine if the repaired specimen would withstand internal pressurization such as that experienced in CO_2 jacketed lines.

Test Conditions

The specimen was installed in a test fixture as shown for Flexure Test on Page 188. Internal pressurization with He was applied to 10 psig plus or minus 2 psig and held for a minimum of two (2) minutes.

Required Data

The specimens repair procedure number and leakage rate were recorded.

3.8.2.8.6 Ruggedness Test

Purpose

To determine if the specimen would withstand rough handling such as might occur during shipment and installation.

Test Conditions

The specimen was installed in a test fixture as shown on Page 189 so that the striking anvil would strike the repaired area. The striking anvil was dropped from a height sufficient to apply a force of 180 pounds on the repaired area, the anvil edge was maintained parallel to the axial center line of the bellows.

Required Data

The specimen repair procedure number and the visually detectable effects of the strike were recorded. Leakage test and leak rate were recorded.

3.8.2.8.7 Flex Cycle Test

Purpose

The purpose of the Flex Cycle Test was to determine the effect of repeated cycling across the repeated area of the test specimen.

Test Conditions

With one end of the specimen in a fixed position, the specimen was flexed so that the flexure occurred across the repaired area. One cycle was the free end of the specimen one half inch contracted, returned to free length, then one half inch extended. A theoretical stress level of 138,000 psi was thus induced. S/N curve data for this design indicated base material would fail at approximately 500 cycles. Although the curve is consecutive, it is in general use and all bellows on flex lines at Launch Complex 39 were based on this original design criteria. One thousand cycles were induced if no failure occurred previous to that number.

Required Data

The specimens repair procedure number and number of flexure cycles, leakage test and leak rate were recorded.

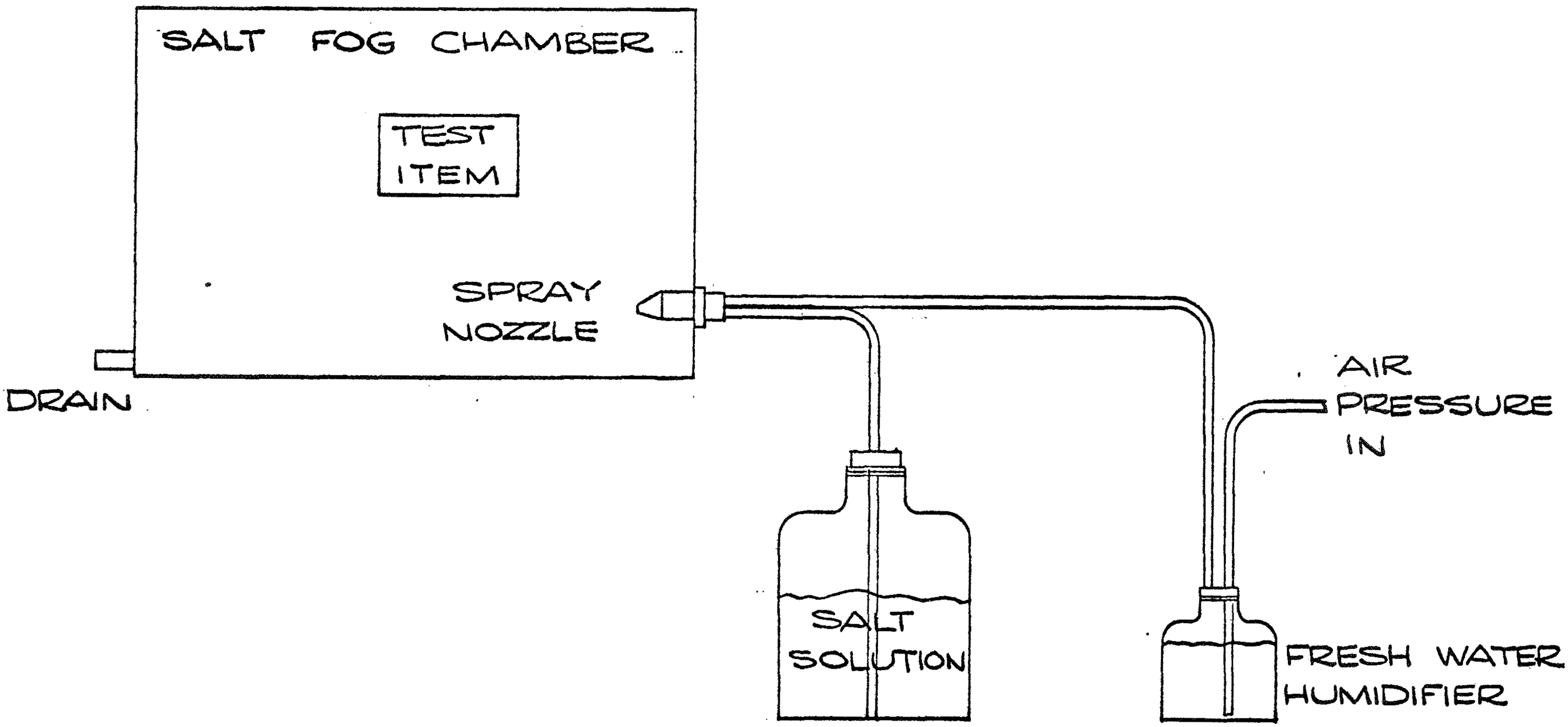


Figure 45. Salt Fog Test Set-up

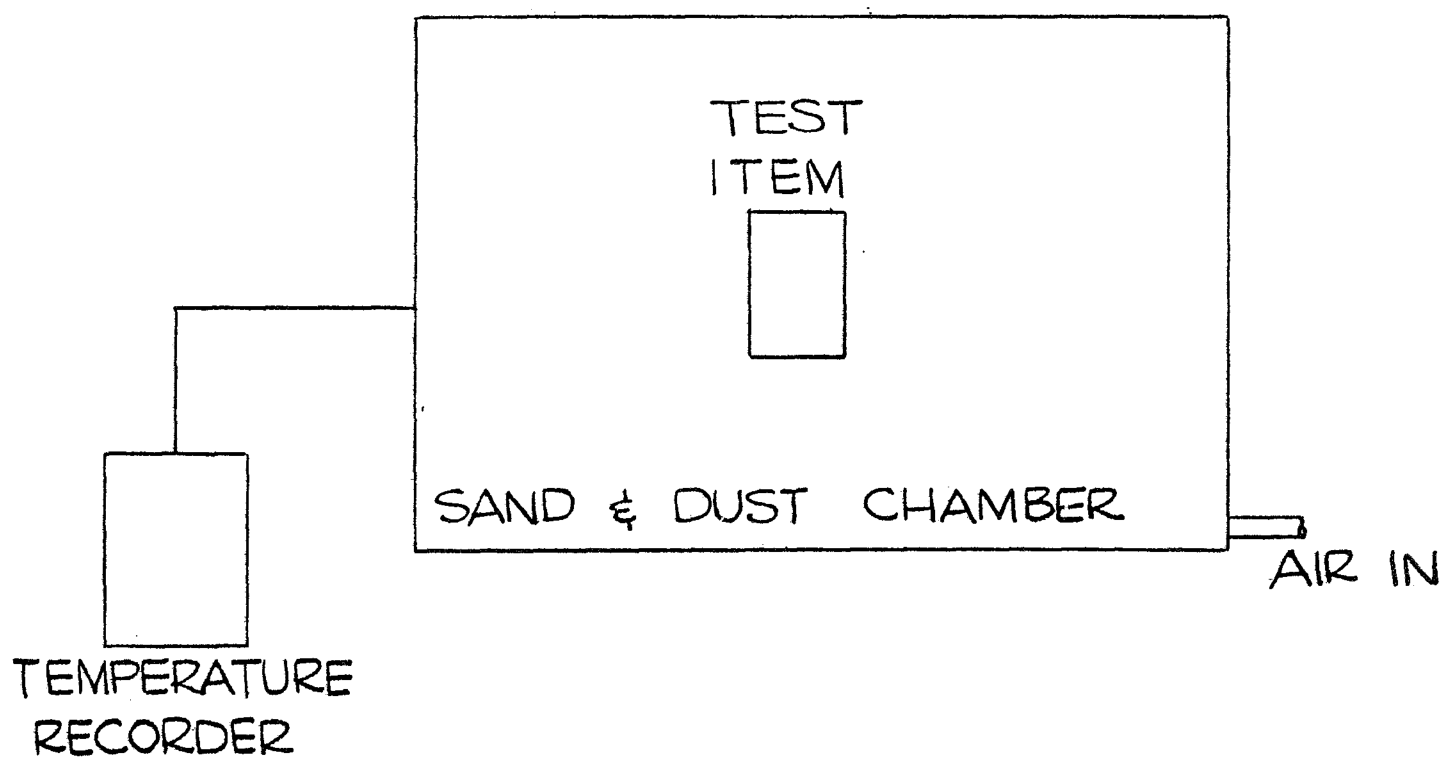


Figure 46. Sand & Dust Test Set-up

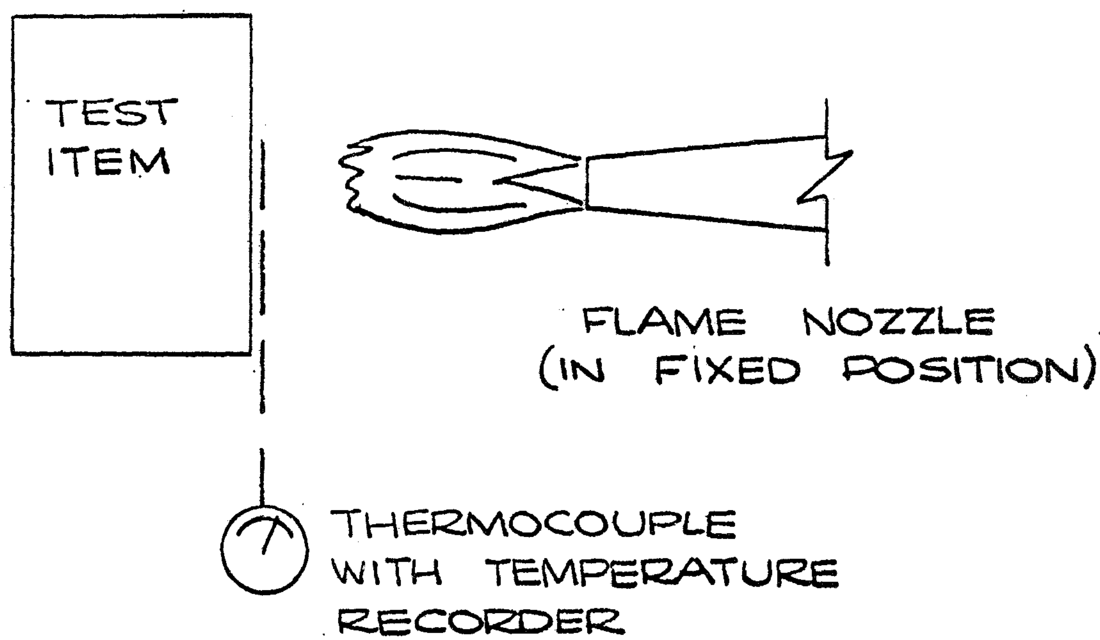


Figure 47. High Temperature Test Set-up

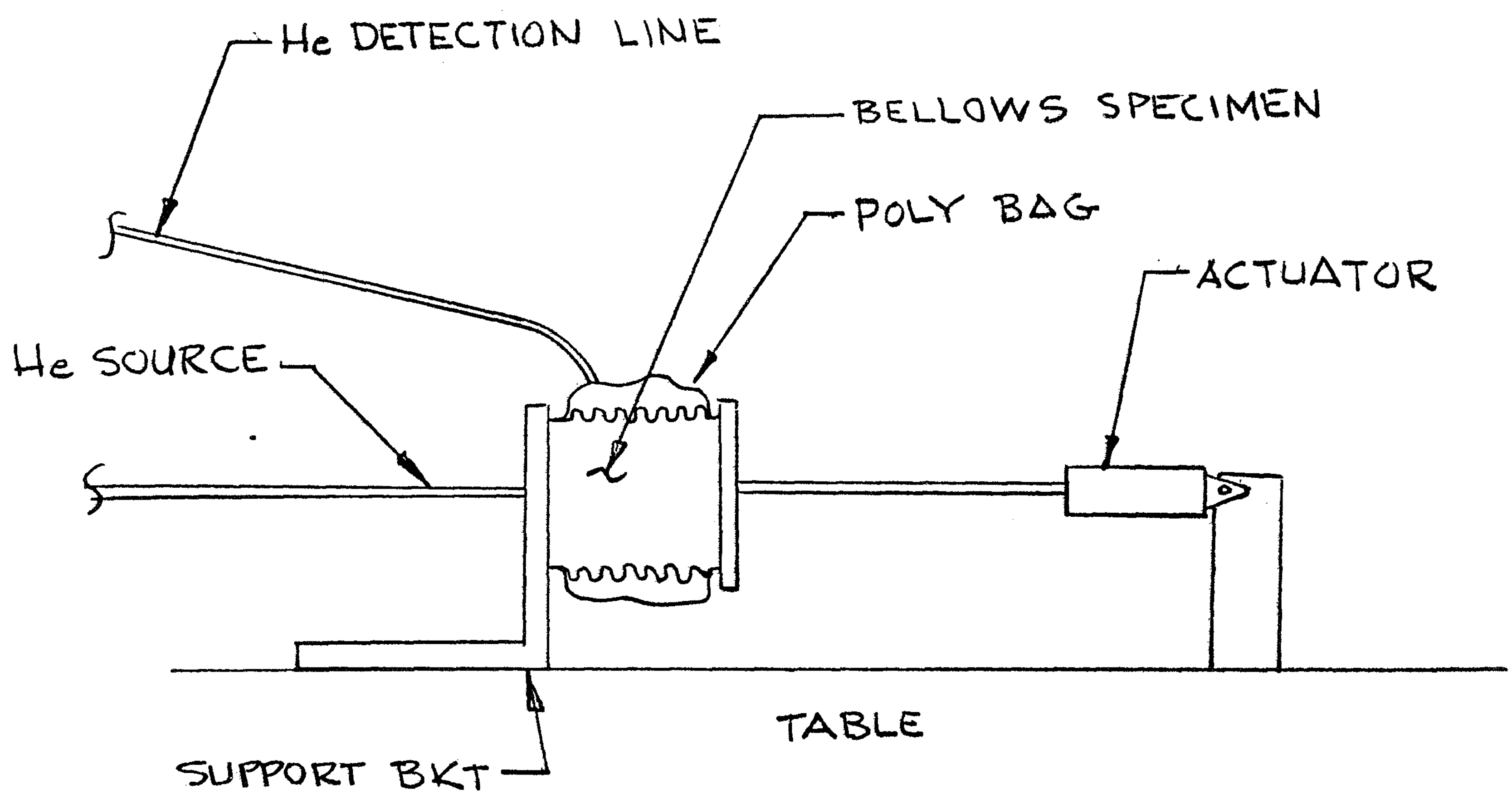


Figure 48. Flex Cycle Test Set-up

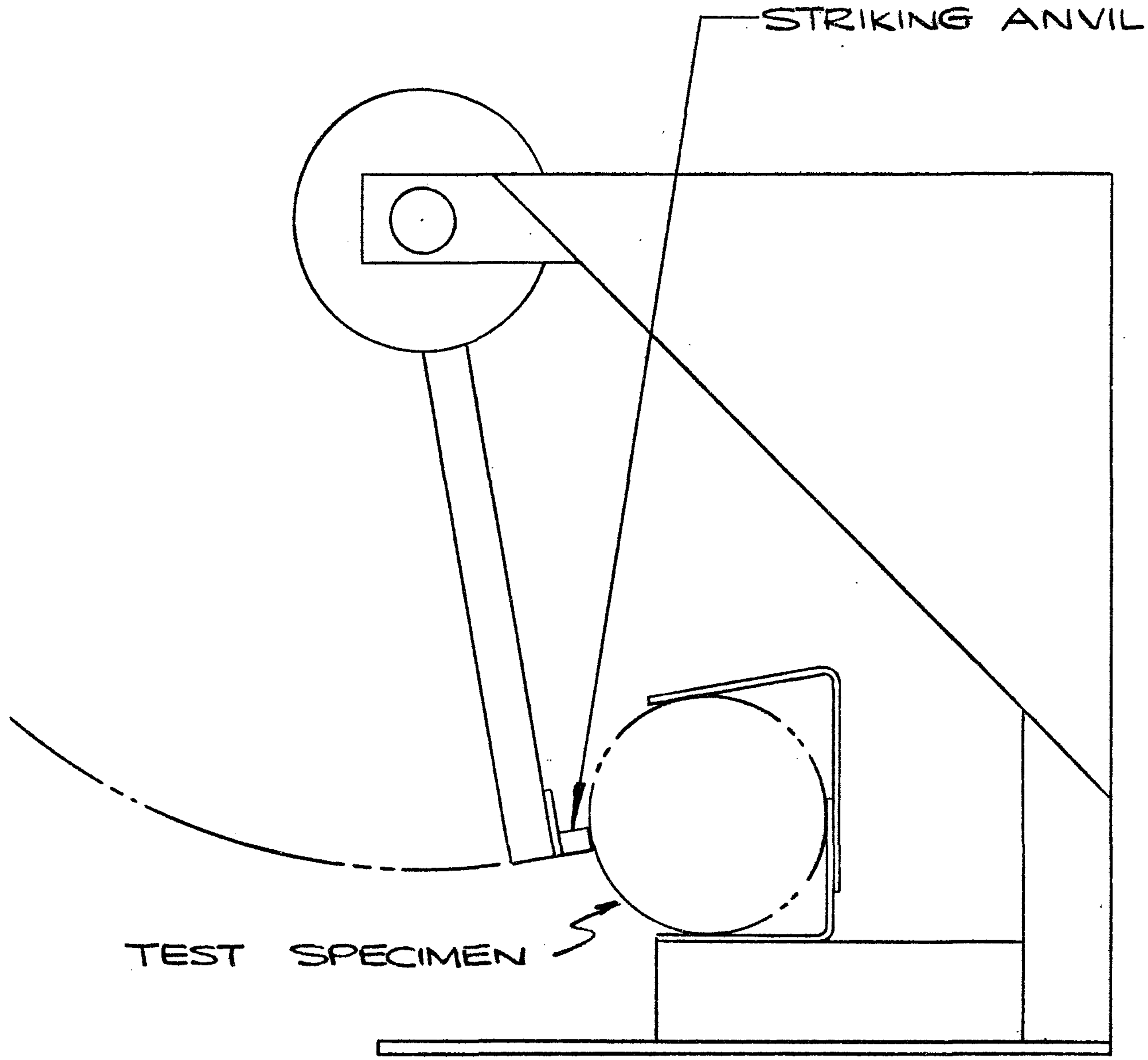


Figure 49. Ruggedness Test Set-up

3.8.2.9 Test Results - Simulated Repair, Data Sheets and Figures

Data sheets and supporting photos reflecting the results of the foregoing testing are given on the following pages of this section.

It should be noted that all tests accomplished on a given repair specimen are included in each test data sheet. The pass and fail column of the data sheet indicates the total number of specimens subjected to any given test. Following the Leak Repair Simulated Repair Data Sheets the test results are summarized by test. Each of these individual test summary sheets presents the results of all material tested for a given type of test. Refer to the Test Flow Chart on Page 179 for the planned number of specimens to be subjected to each test.

LEAK REPAIR SIMULATED REPAIR

TEST DATA SHEET

Material/Method Dow Corning #732 RTV

Repair Procedure P4058-1A

Test Procedure 8-480094

TEST RESULTS

TEST	Date	Pass	Fail	Leakage not measurable	Leakage rate
Salt Spray		(2)			
Sand and Dust		(2)			
Flexure		(2)			
Cold Shock		(2)			
High Temperature		(2)			
Internal Pressure		(2)			
Ruggedness		(1)	(1)	#	

Comments:

Test Technician [signature]

Test Engineer K Knibel

LEAK REPAIR SIMULATED REPAIR

TEST DATA SHEET

Material/Method Johns - Manville "Volseal"

Repair Procedure P4058-13A

Test Procedure 8-480094

TEST RESULTS

TEST	Date	Pass	Fail	Leakage not measurable	Leakage rate
Salt Spray		(2)			
Sand and Dust		(2)			
Flexure		(2)			
Cold Shock		(2)			
High Temperature		(2)			
Internal Pressure		(2)			
Ruggedness		(2)			

Comments:

Test Technician [signature]

Test Engineer K Kuhle

LEAK REPAIR SIMULATED REPAIR

TEST DATA SHEET

Material/Method Braze with Silvalloy #45

Repair Procedure P4058-14C

Test Procedure 8-480094

TEST RESULTS

TEST	Date	Pass	Fail	Leakage not measurable	Leakage rate
Salt Spray		(2)			
Sand and Dust		(2)			
Flexure		(2)			
Cold Shock		(2)			
High Temperature		(2)			
Internal Pressure		(2)			
Ruggedness		(2)			

Comments:

Test Technician [signature]

Test Engineer [signature]

LEAK REPAIR SIMULATED REPAIR

TEST DATA SHEET

Material/Method TIG (Tungsten electrode, inert gas, arc weld)

Repair Procedure P4058-15D

Test Procedure 8-480094

TEST RESULTS

TEST	Date	Pass	Fail	Leakage not measurable	Leakage rate
Salt Spray		(2)			
Sand and Dust		(2)			
Flexure		(2)			
Cold Shock		(2)			
High Temperature		(2)			
Internal Pressure		(2)			
Ruggedness		(2)			

Comments:

Test Technician [signature]

Test Engineer K Kuhl

LEAK REPAIR SIMULATED REPAIR

TEST DATA SHEET

Material/Method Soft Solder 60/40

Repair Procedure P4058-18B

Test Procedure 8-480094

TEST RESULTS

TEST	Date	Pass	Fail	Leakage not measurable	Leakage rate
Salt Spray		(2)			
Sand and Dust		(2)			
Flexure		(1)	(1)	#	
Cold Shock		(2)			
High Temperature		(1)	(1)		3×10^{-7}
Internal Pressure		(1)	(1)		3×10^{-7}
Ruggedness		(1)	(1)	#	

Comments:

Test Technician [signature]

Test Engineer K Kuble

LEAK REPAIR SIMULATED REPAIR

TEST DATA SHEET

SALT SPRAY TEST

MATERIAL	TEST RESULTS	COMMENTS
J-M Volseal	No failures	
Silvalloy #45 Braze	No failures	
Heliarc (TIG) Weld	No failures	
Dow-Corning #732	No failures	
Soft-Solder 60/40	No failures	

LEAK REPAIR SIMULATED REPAIR

TEST DATA SHEET

SAND AND DUST TEST

MATERIALS	TEST RESULTS	COMMENTS
J-M Volseal	No Failures	
Silvalloy #45 Braze	No Failures	
Heliarc (TIG) Weld	No Failures	
Dow Corning #732	No Failures	
Soft Solder 60/40	No Failures	

LEAK REPAIR SIMULATED REPAIR

TEST DATA SHEET

COLD SHOCK TEST

MATERIAL	TEST RESULTS	COMMENTS
J-M Volseal	No Failures	
Silvalloy #45 Braze	No Failures	
Heliarc (TIG) Weld	No Failures	
Dow Corning #732	No Failures	
Soft Solder 60/40	No Failures	

LEAK REPAIR SIMULATED REPAIR

TEST DATA SHEET

HIGH TEMPERATURE TEST

MATERIAL	TEST RESULTS	COMMENTS
J-M Volseal	No Failures	
Silvalloy #45 Braze	No Failures	
Heliarc (TIG) Weld	No Failures	
Dow Corning #732	No Failures	
Soft Solder 60/40	(1) Passed (1) Failed*	*3 X 10^{-7} cc/sec. helium leak rate

LEAK REPAIR SIMULATED REPAIR

TEST DATA SHEET

FLEX CYCLE TEST

MATERIALS	TEST RESULTS	COMMENTS
J-M Volseal	No Failures	
Silvalloy #45 Braze	No Failures	
Heliarc (TIG) Weld	No Failures	
Dow Corning #732	No Failures	
Soft Solder 60/40	(1) Passed (1) Failed	Solder appeared to be a thinner coating on failed specimen

LEAK REPAIR SIMULATED REPAIR

TEST DATA SHEET

INTERNAL PRESSURE TEST

MATERIALS	TEST RESULTS	COMMENTS
J-M Volseal	No Failures	
Silvalloy #45 Braze	No Failures	
Heliarc (TIG) Weld	No Failures	
Dow Corning #732	No Failures	
Soft Solder 60/40	(1) Pass (1) Fail *	*3 X 10^{-7} cc/sec helium leak rate.

LEAK REPAIR SIMULATED REPAIR

TEST DATA SHEET

RUGGEDNESS TEST

MATERIALS	TEST RESULTS	COMMENTS
J-M Volseal	No Failures	
Silvalloy #45 Braze	No Failures	
Heliarc (TIG) Weld	No Failures	
Dow-Corning #732	(1) Failed* (1) Passed	*Leakage rate was too high to be measurable on mass spectrometer. Appearance showed no indication of damage, however the material must be considered questionable for this test.
Soft Solder 60/40	(1) Pass (1) Failed*	*Leak rate not measurable on mass spectrometer

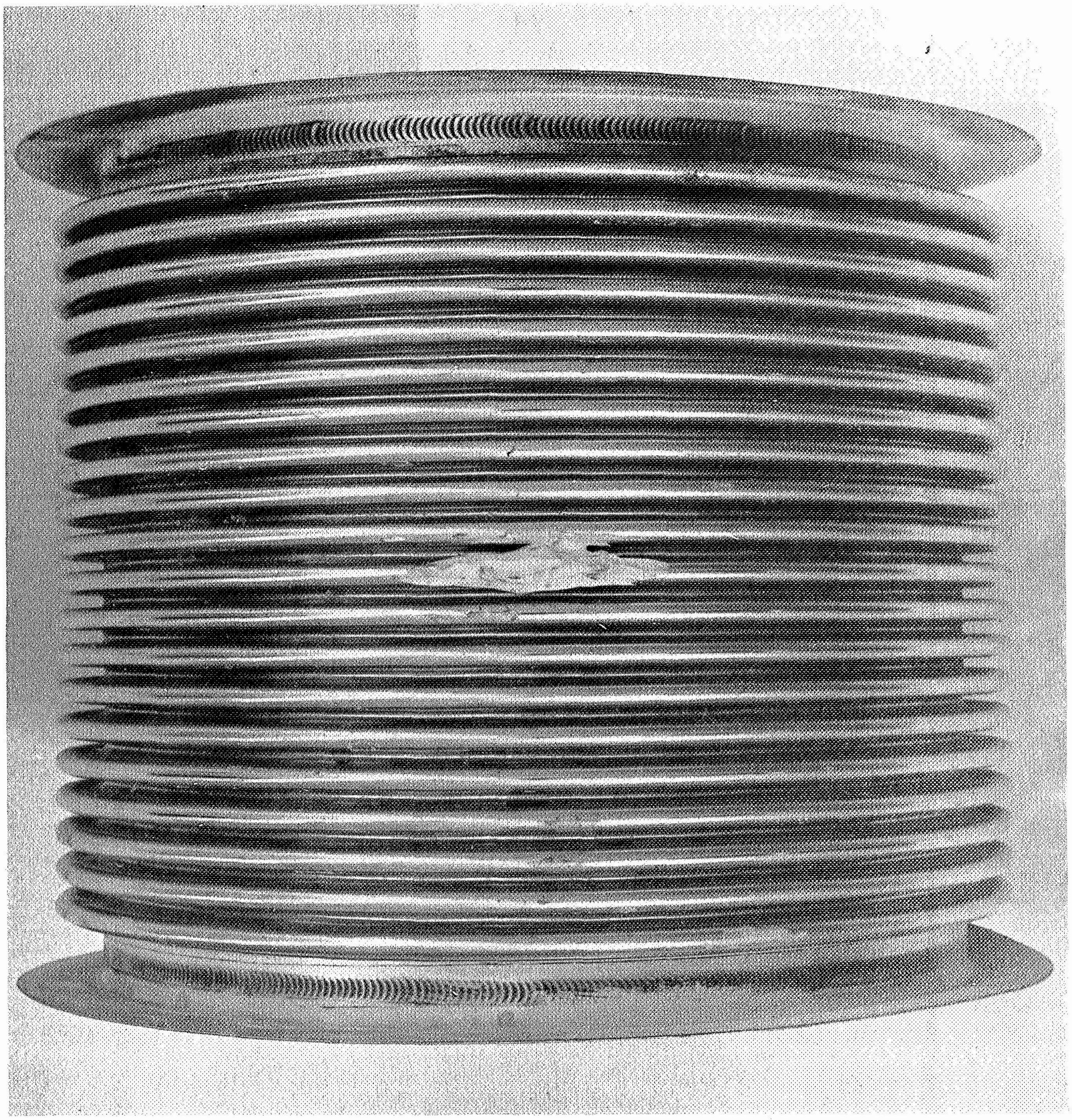


Figure 50. Simulated Repair Specimen Per PA4058-1A

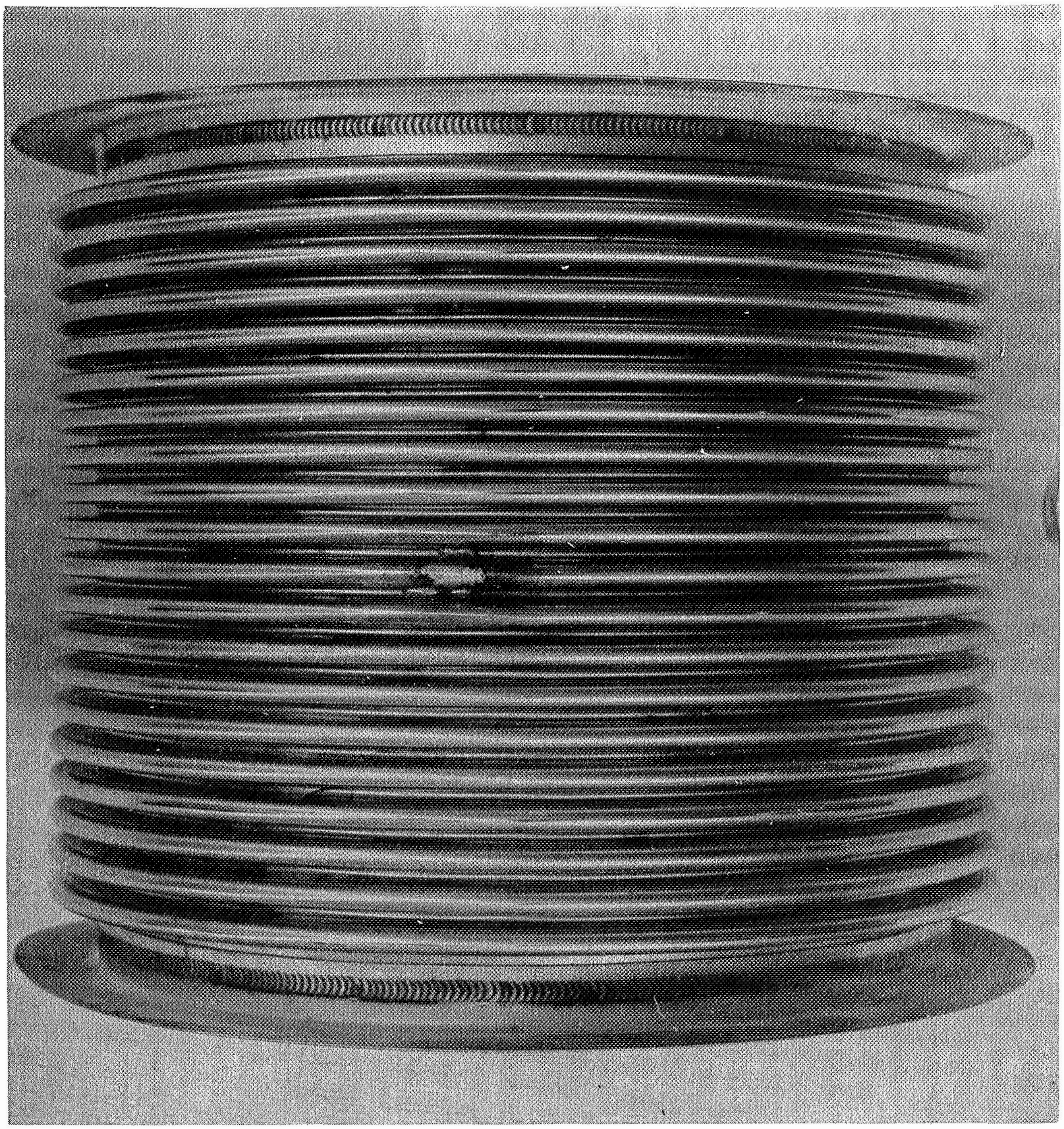


Figure 51. Simulated Repair Specimen Per PA4058-14C

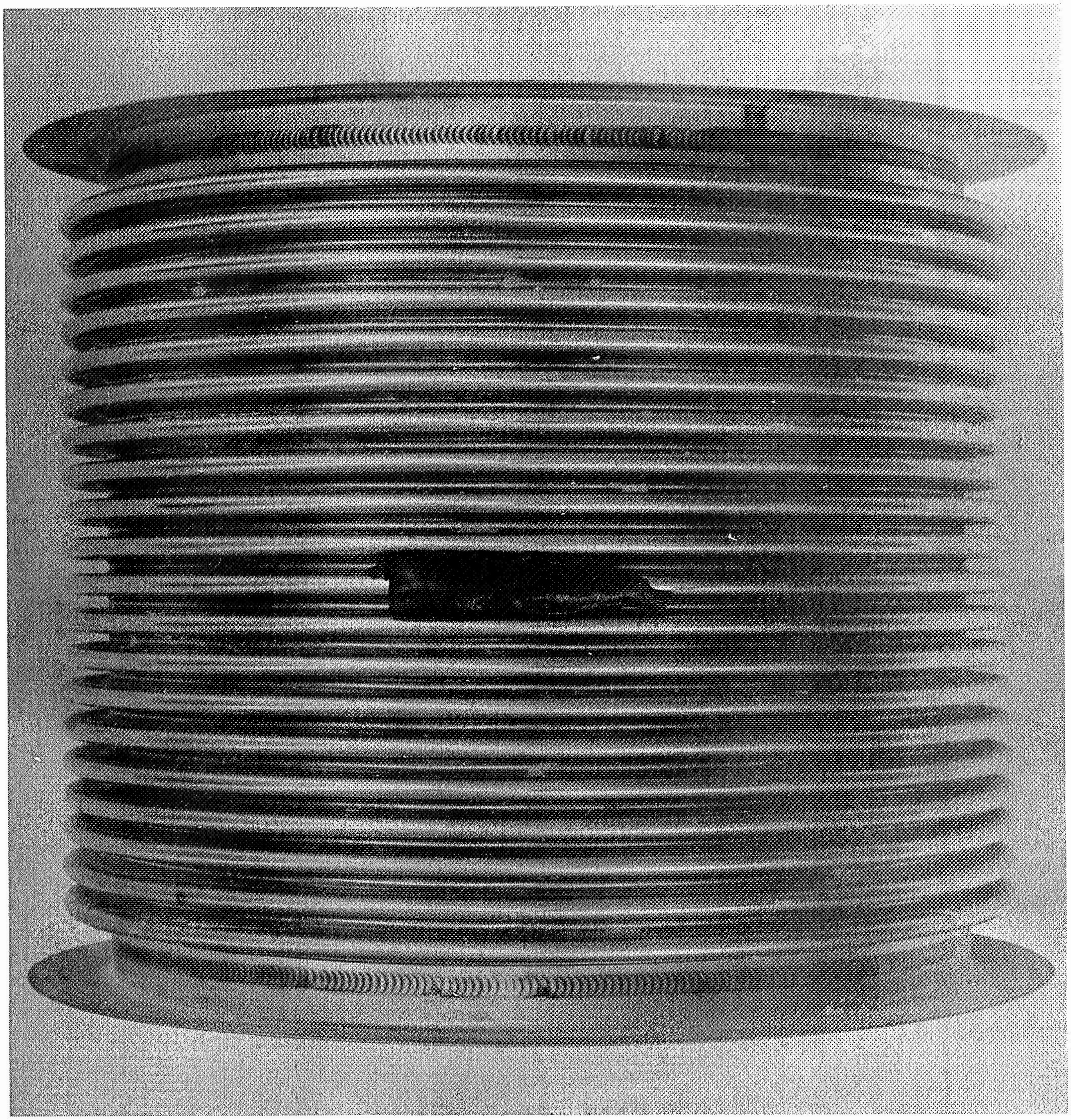


Figure 52. Simulated Repair Specimen Per PA4058-13A

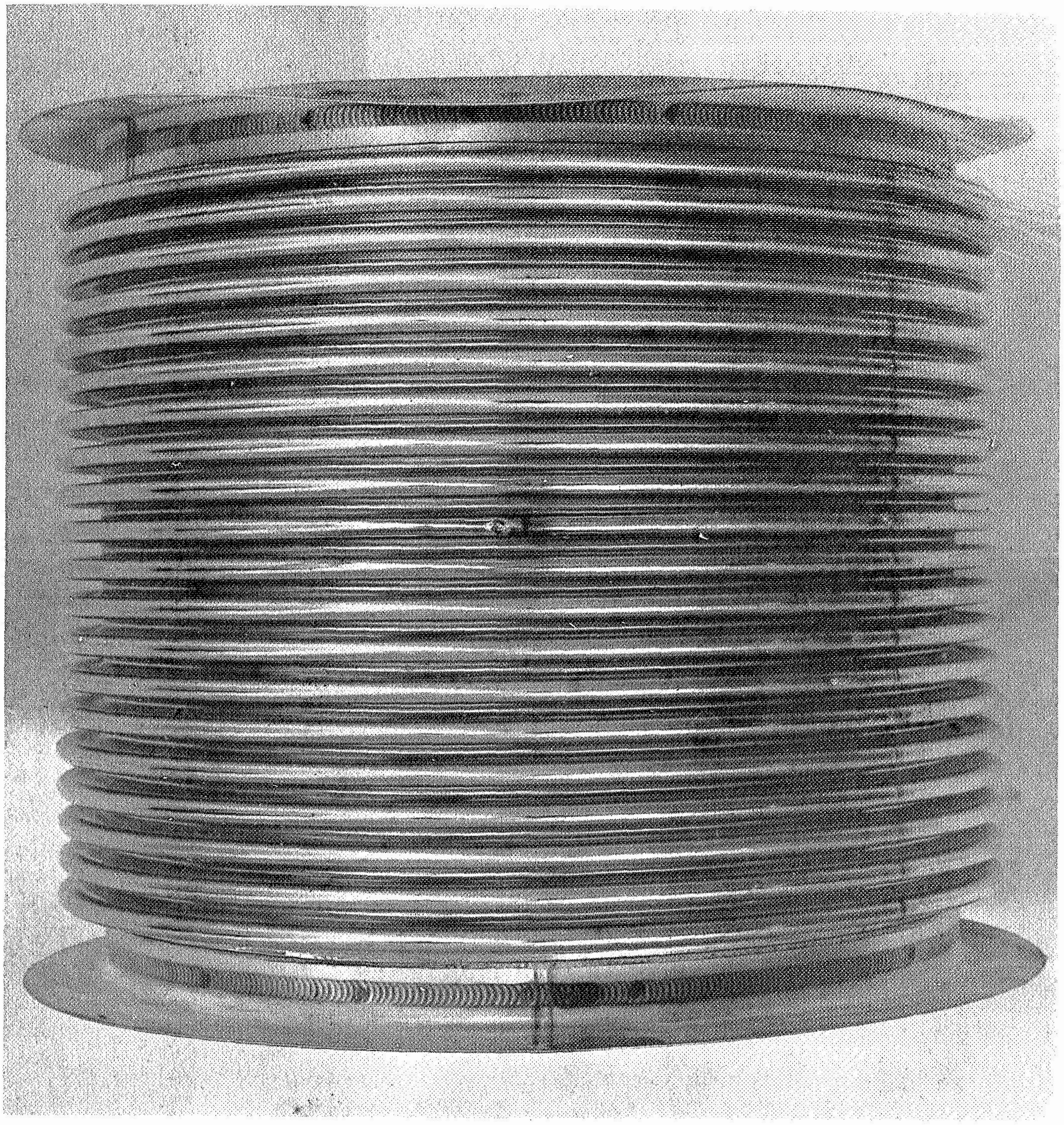


Figure 53. Simulated Repair Specimen Per PA4058-15D

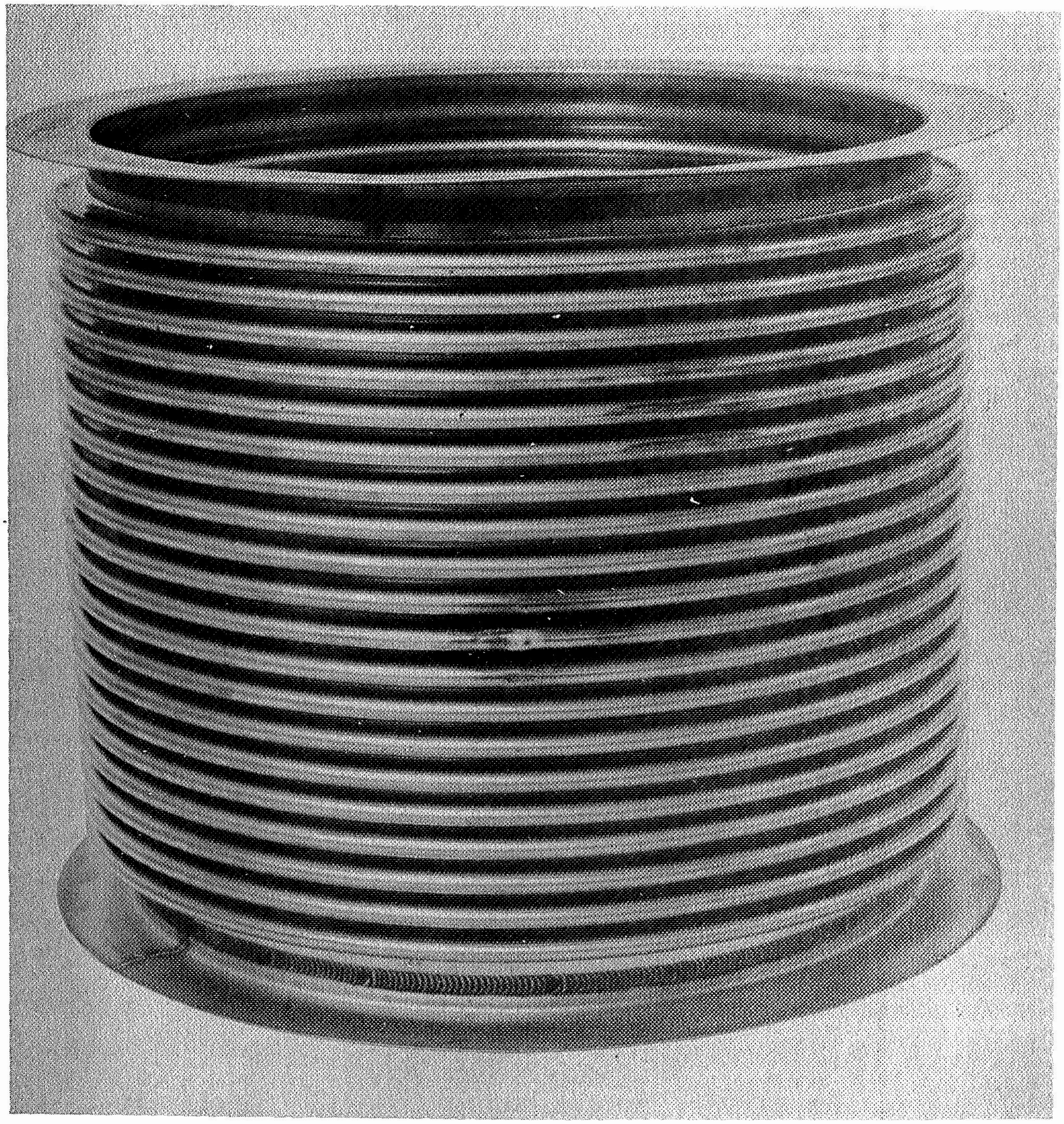


Figure 54. Simulated Repair Specimen Per PA4058-18B

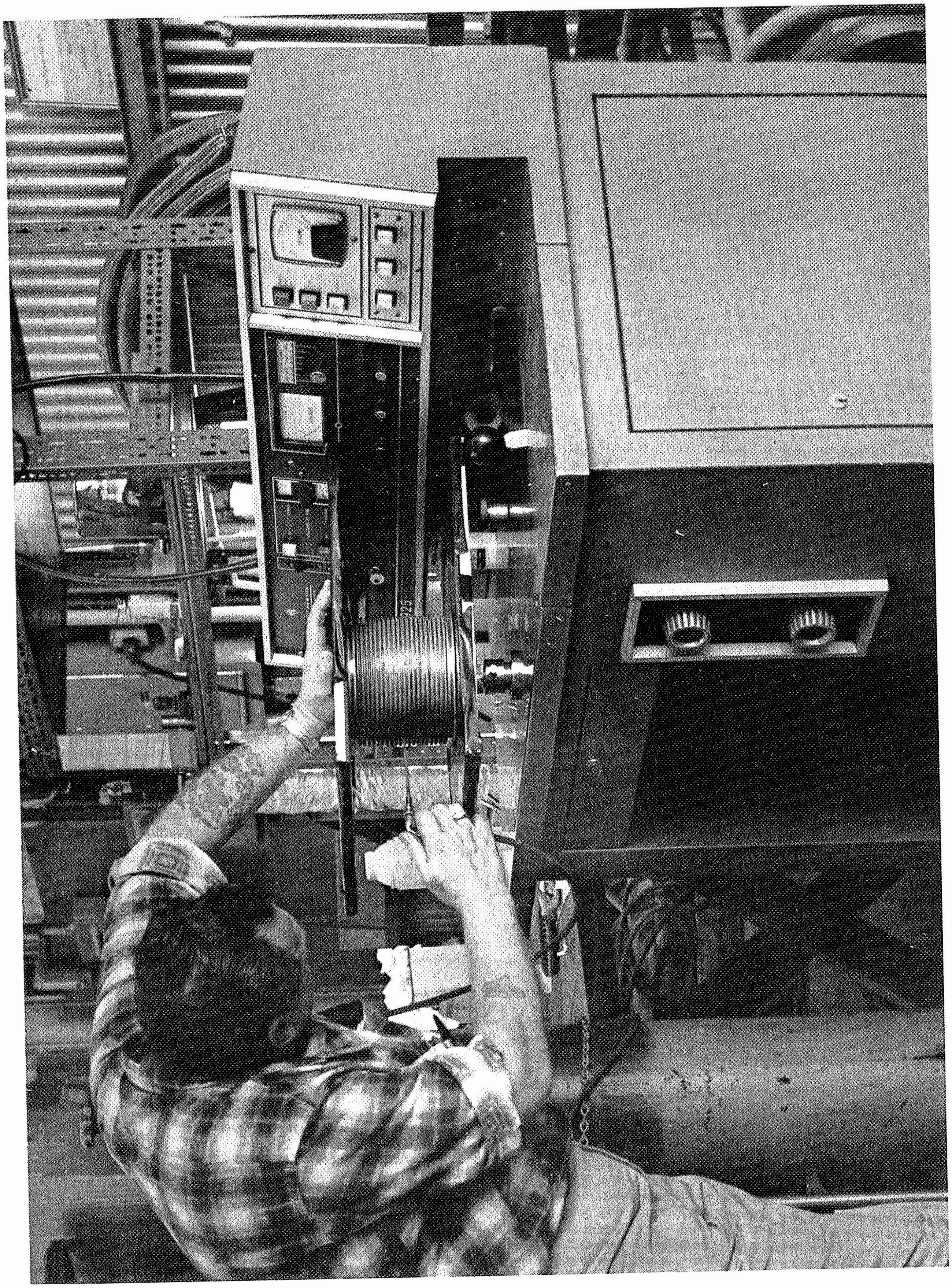


Figure 55. Simulated Repair - Helium Leak Test Set-up

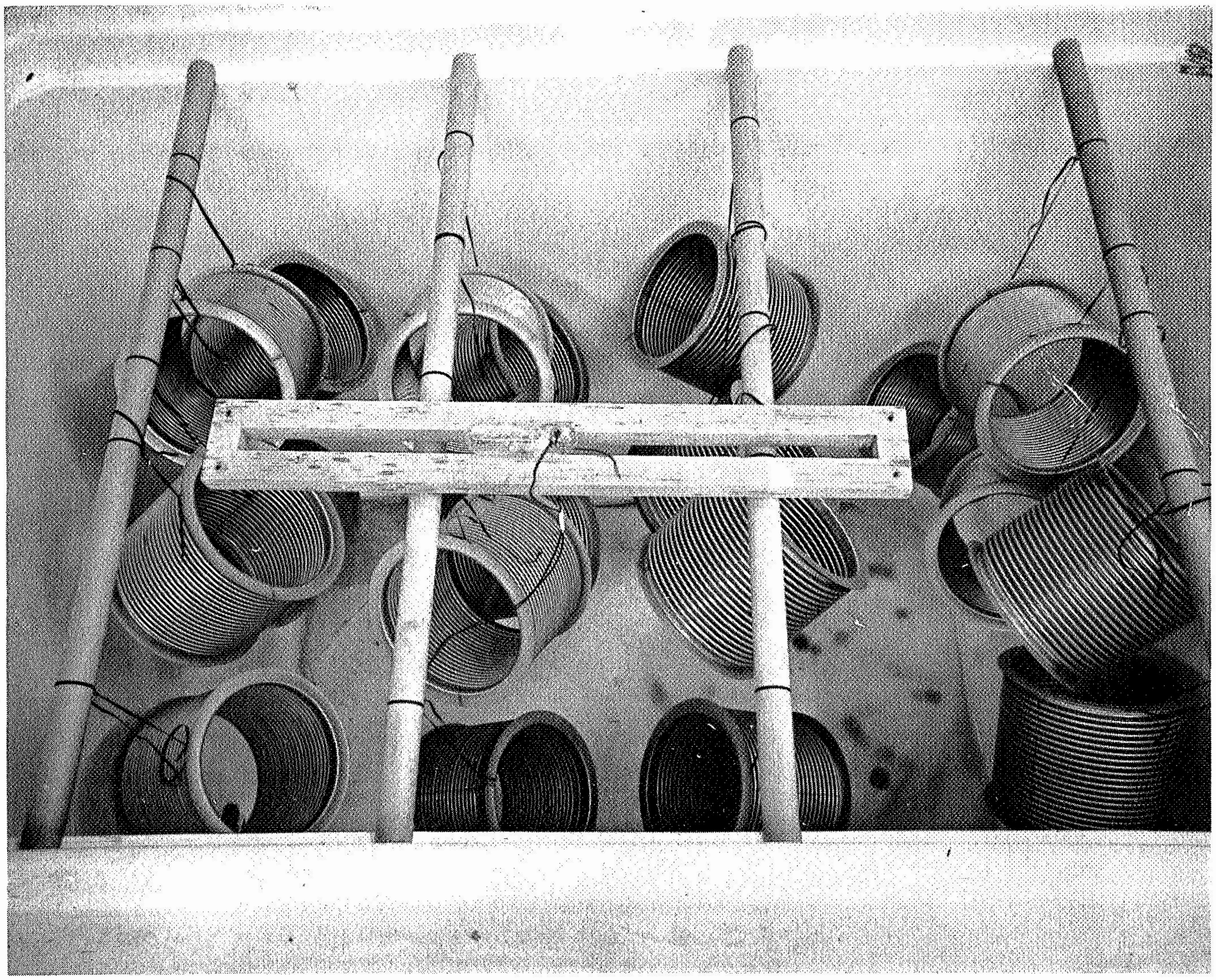


Figure 56. Salt Fog Test Set-up - Simulated Repair Specimens

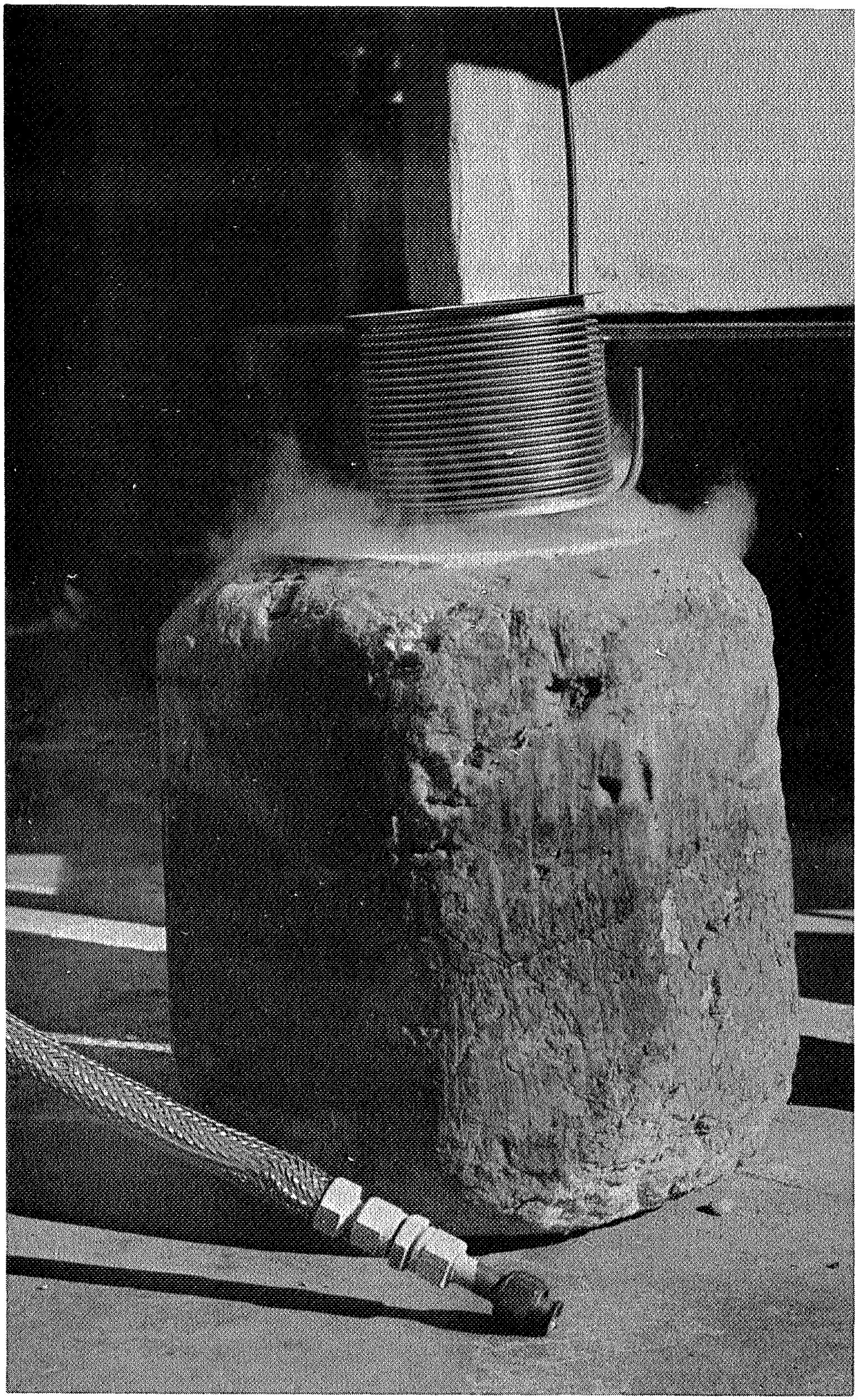


Figure 57. Simulated Repair Specimen - Low Temperature Test Set-up

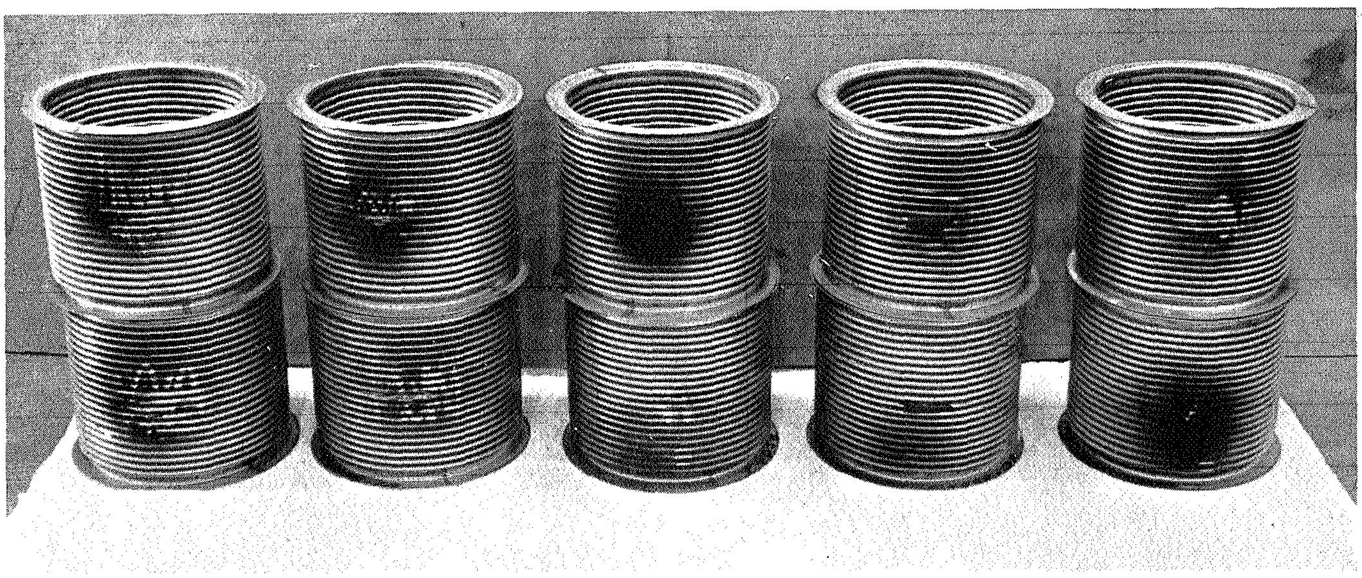


Figure 58. Simulated Repair Specimen - After High Temperature Testing

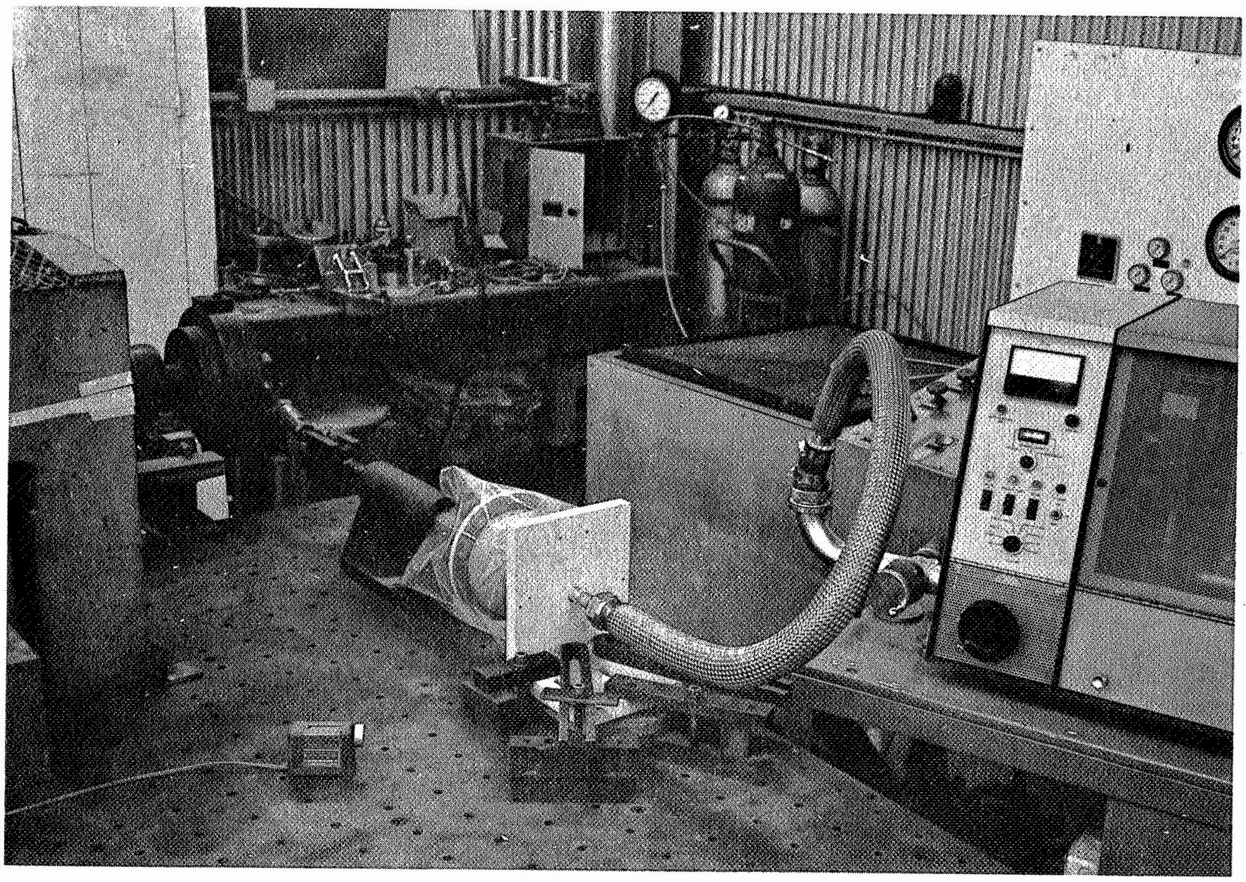


Figure 59. Simulated Repair - Flexure Test Set-up

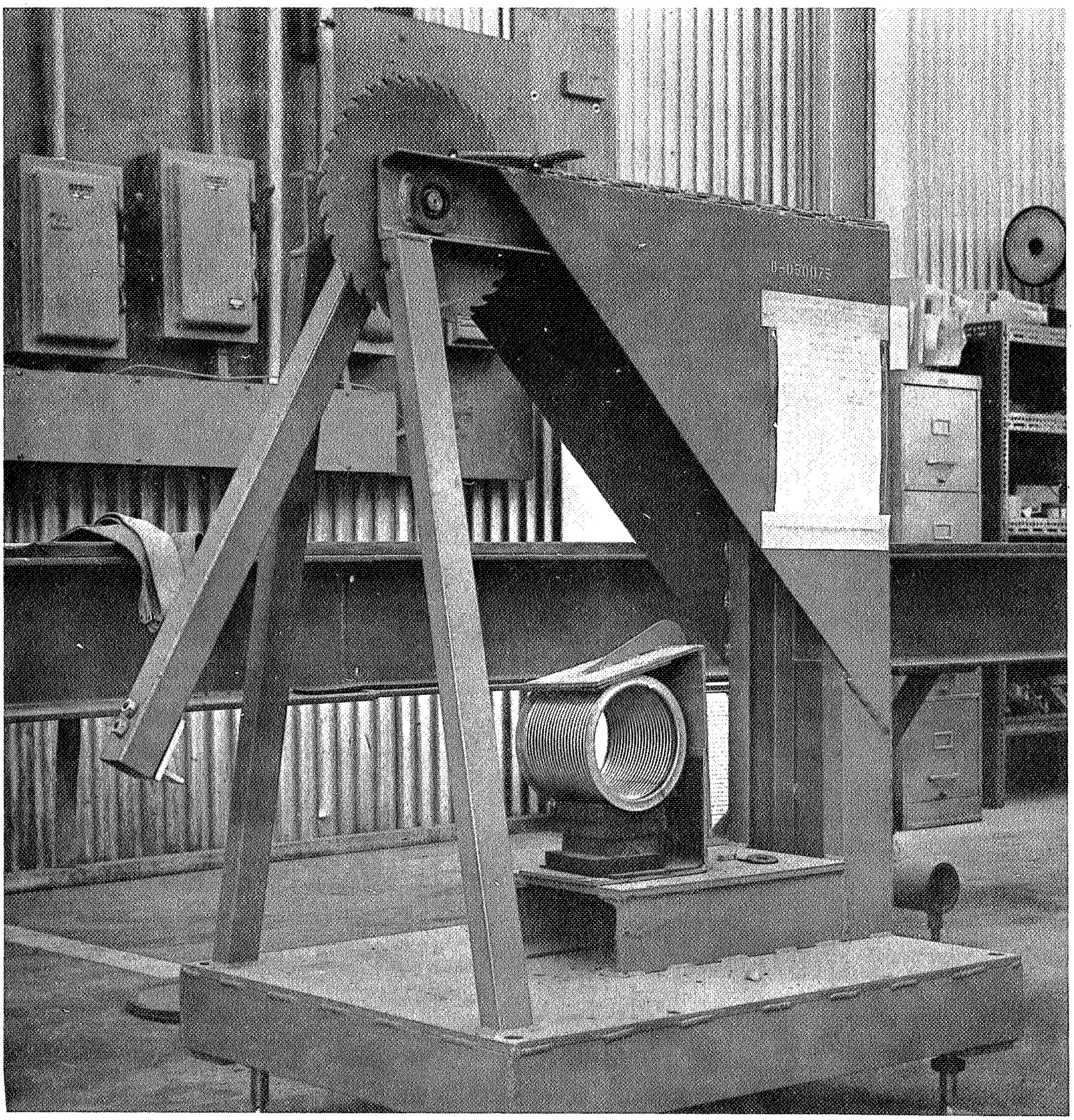


Figure 60. Simulated Repair - Ruggedness Testing Set-up

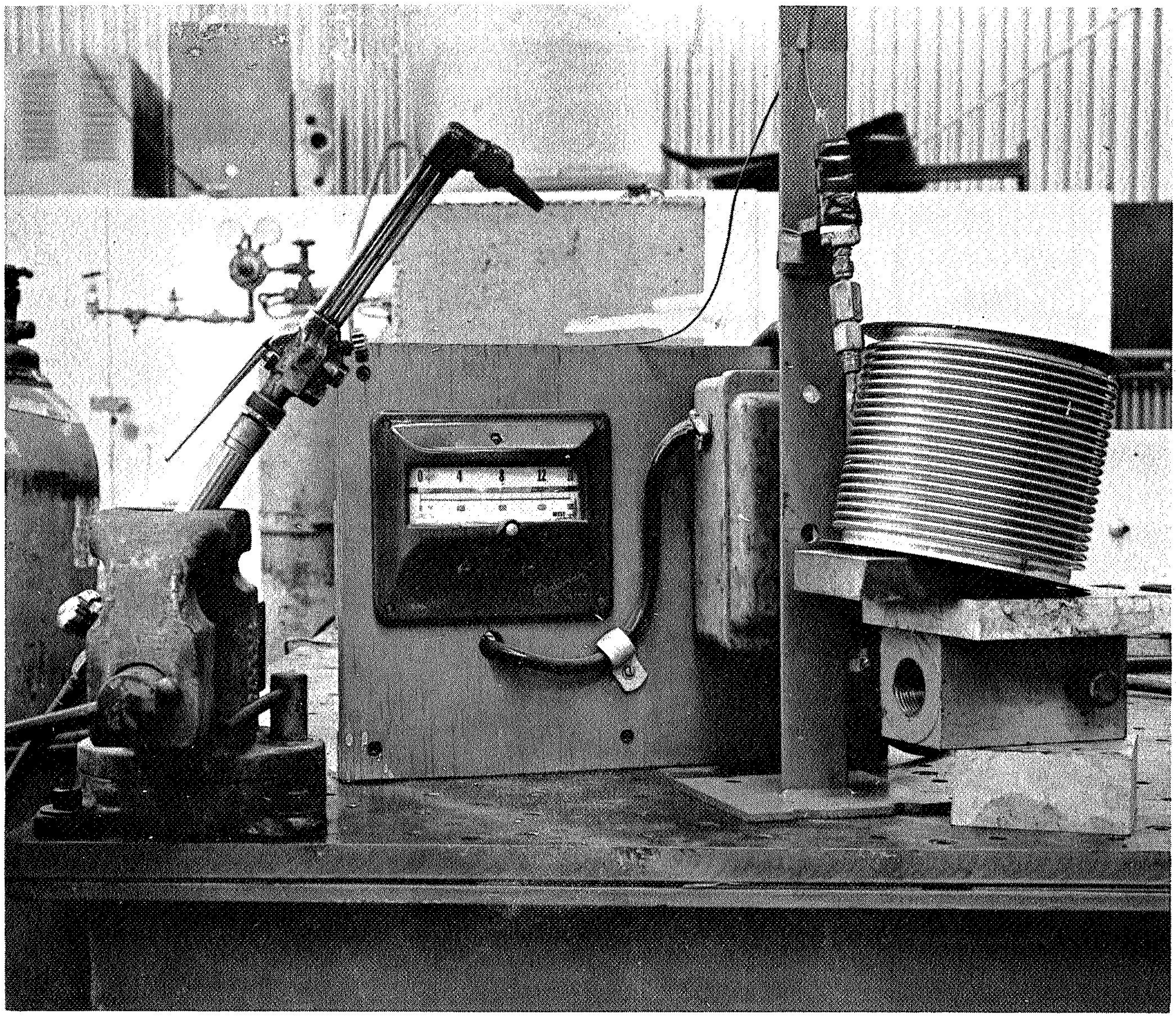


Figure 61. Simulated Repair - High Temperature Testing Set-up

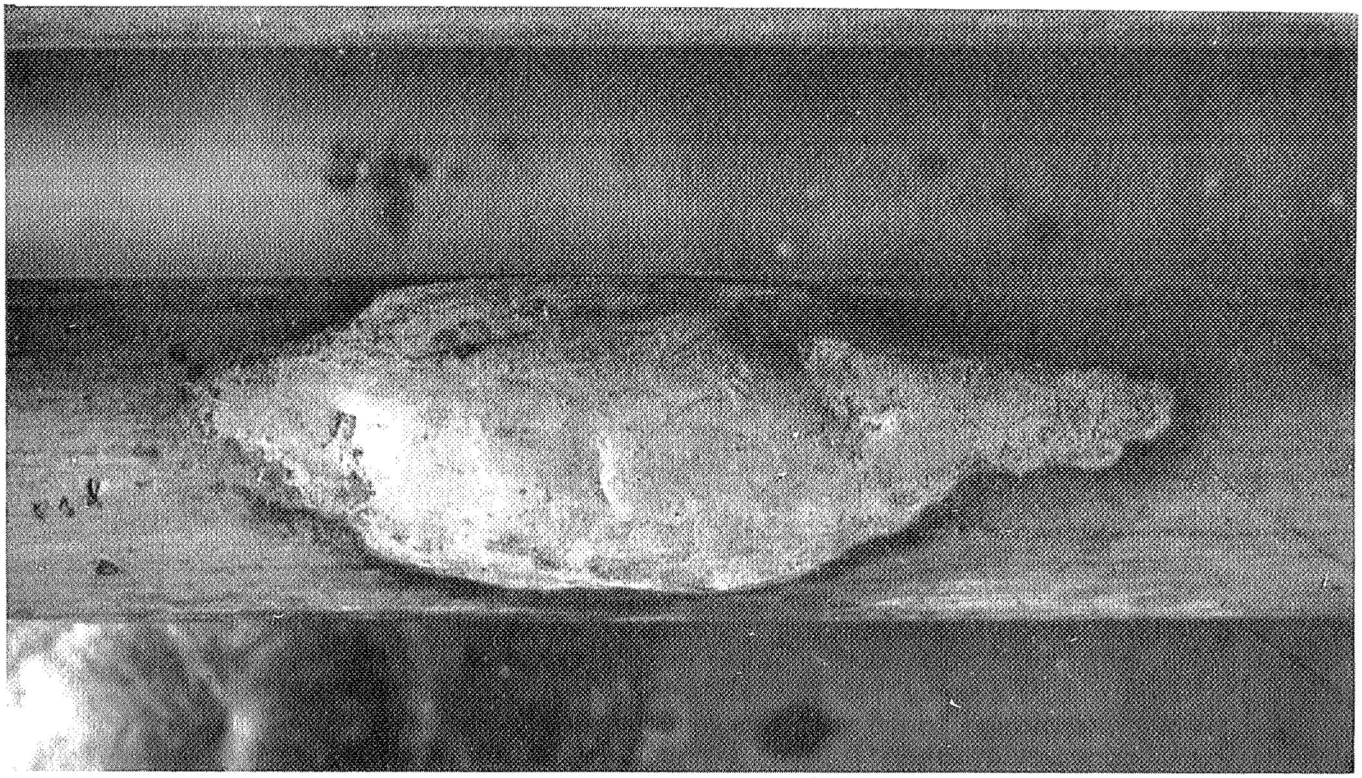


Figure 62. Simulated Repair Specimen Per PA4058-18B (Soft Solder) Passed All Tests

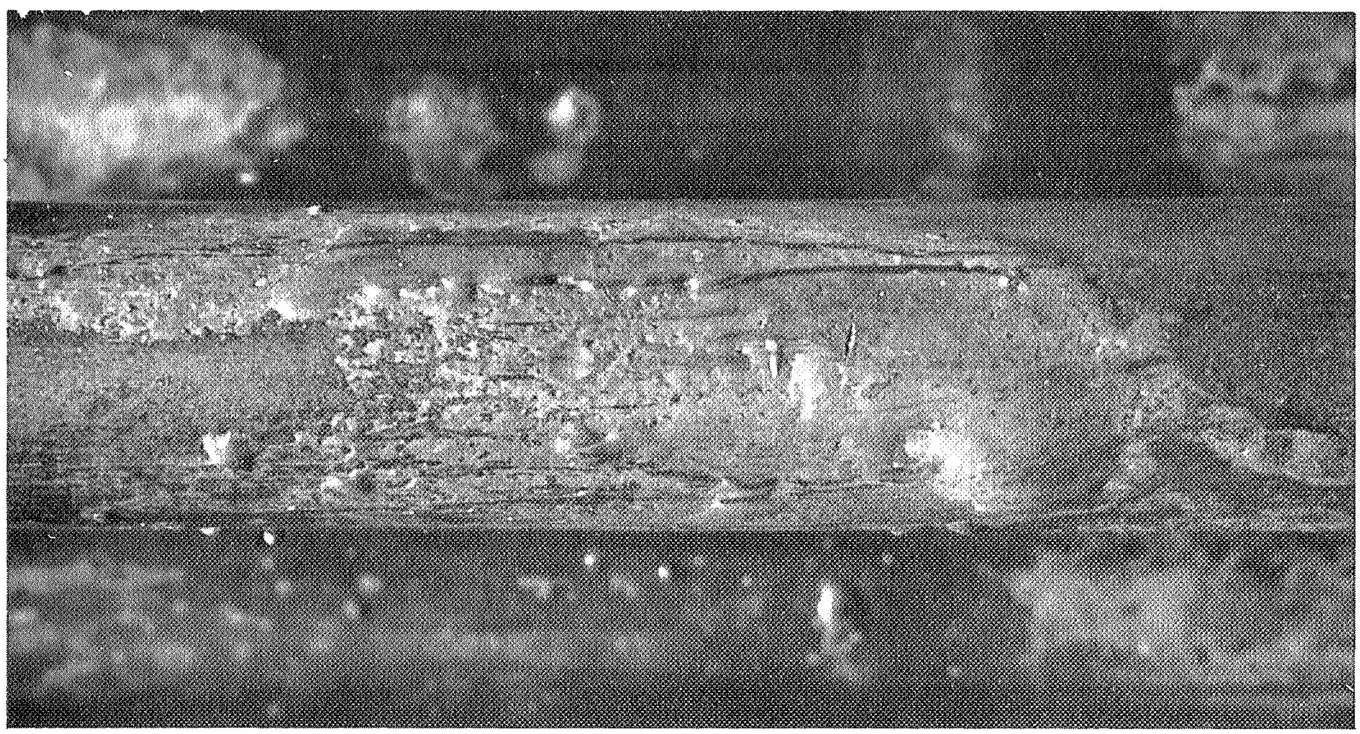


Figure 63. Simulated Repair Specimen Per PA4058-18B Failed in Flex Test

3.9 Field Repair Procedures

The Field Repair Procedures which follow, are in their final form and reflect the recommended methods of using the materials given. The Simulated Repairs testing shows that the number one choice for temporary repairs is the P4058-13A Johns-Manville "Volseal" and that the first choice of permanent field repair techniques would be either welding (thick materials over .016 inch) or silver solder for thinner materials. It is recommended that the soft solder and RTV silicone rubber be used where they would not be exposed to abrasion or impact loads.

During testing of the "Volseal" it was noted that it gains adhesion with time and may, therefore, be considered for permanent repairs with further long-term testing. The foregoing is also true to some extent of the RTV silicone rubber.

Welding should never be used when repair is in close proximity to insulation material or molecular sieve in the annular space of a vacuum jacket. Generally, whenever the damaged metal is thin enough to allow quick heat transfer, brazing would be recommended over welding since it is easier to transport the smaller equipment and easier for the operator to apply without chance of damaging mistakes.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P 4058-1A

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Dow Corning #732 RTV (Silicone Rubber)

Equipment Required

None

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

   Wipe entire area on and 1.0" (Min.) adjacent to repair with clean Kimwipe dipped in acetone to remove grease and contaminants. Allow to dry completely.

2. Safety precautions.

   Un-cured silicone rubber releases acetic acid. In case of contact flush with water immediately. Eye tissue can be permanently damaged.

3. Application of repair (Technique).

   Fill damaged area with 1/16 to 1/8 inch thick coat by squeezing tube and moving nozzle close to repair area. Make coating an even thickness extending .250 to .500 inch beyond hole in all directions. Sealant is non-flowing after 10 minutes. Allow one hour for cure and 24 hours for full strength.

4. Post-repair cleaning, precautions, checks, etc.

   None

5. Re-repair preparation of unsuccessful repair area.

Cut or peel off as much as possible of the old sealant, removing any foreign matter. Take care to use clean blade or other tool for this purpose.

6. Re-repair application technique.

Starting with step 1 of the procedure, continue as with new repair.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P 4058-13A

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

"Volseal" (Johns-Manville)

Equipment Required

None

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

Wipe repair area with acetone using clean Kimwipe. Remove all grease and foreign matter.

2. Safety precautions.

No special precautions.

3. Application of repair (Technique).

Pinch off small portion of repair material and roll into ball approximately 1/4 inch in diameter. Press ball onto hole and flatten to form 1/16 inch thick disc with 1/4 inch minimum edge distance from hole edges. Feather out the edges of repair material to form smooth transition with no lumps or creases.

4. Post-repair cleaning, precautions, checks, etc.

Check for porosity in repair material.

5. Re-repair preparation of unsuccessful repair area.

Remove entire amount of repair material originally applied.

6. Re-repair application technique.

Starting with step one of the procedure proceed as with original repair.

Repaired four (4) specimens per procedure.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P4058-14C

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Silvaloy # 45 Silver Solder wire .032 inch diameter.

Equipment Required

Propane torch or Oxy-Acetalene equipment.

CRES 18-8 wire brush

"Black Flux" for brazing

Nitric Acid

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

Using clean, dry CRES 18-8 wire brush, buff repair area to bright finish. Apply Black Flux generously over entire repair area.

2. Safety precautions.

Provide good ventilation, brazing wire contains cadmium.

3. Application of repair (Technique).

Holding end of brazing wire near base metal, heat both with torch until wire flows onto base metal. Do not heat base metal higher than necessary. Prolonged heating should be avoided. Make repair as quickly as is convenient. Edge distance from hole to edge of overlapping braze filler when finish should be 1/16 inch to 1/8 inch. Avoid excess filler. Use wet rag as quench to cool quickly after application.

4. Post-repair cleaning, précautions, checks, etc.

Wipe off flux with water on clean rag. Wire brush to bright finish. Using 50% (by volume) nitric acid in water solution, swab repair area thoroughly. Allow acid to remain for thirty minutes, re-swabbing as necessary. Rinse with de-ionized water spray. Check visually for porosity or gaps.

5. Re-repair preparation of unsuccessful repair area.

Same as Step 6.

6. Re-repair application technique.

Starting with step one of the procedure, proceed as with original repair.

Repaired four (4) specimens per procedure.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P4058-15D

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Type 300 series CRES Welding rod (.020 inch dia.)

Equipment Required

150 amp (min) DC Heliarc Welding power supply with
Argon Cup gas feed.
CRES 18-8 wire brush
Nitric Acid

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

Using clean, dry CRES 18-8 wire brush, buff repair area to bright finish.

2. Safety precautions.

Protect eyes from arc at all times.

3. Application of repair (Technique).

Welding Schedule:

Amperage - 10 to 12. Voltage - 8 to 10

Cup Gas - Straight Argon, Flow - 15 ft 3/hr.

Polarity - Straight electrode - 2% thoriated tungsten

Procedure - Strike arc with electrode very close to hole. Simply push the filler rod in one quick strike on the hole and shut down the arc. Place wet rag over repaired area to quench quickly.

4. Post-repair cleaning, précautions, checks, etc.

Wire brush repair to bright finish. Using 50% (by volume) nitric acid in water solution, swab area thoroughly. Allow acid to remain for thirty minutes, re-swabbing as necessary. Rinse with de-ionized water spray. Check visually for hole coverage.

5. Re-repair preparation of unsuccessful repair area.

Same as Step 6.

6. Re-repair application technique.

Starting with step one of the procedure, proceed as with original repair.

Repaired four (4) specimens per procedure.

PROCEDURE - FIELD REPAIR
VACUUM & CO_2 JACKETED LINES

Procedure Number P4058-18B

Heat Range Category

A - No heat

B - Low heat

C - Moderate heat

D - High heat

Basic Material(s) of Repair

Soft Solder 60% tin/40% lead

ASTM Class 60A (374^{o}F Liquidus Temp.)

Equipment Required

Propane torch or equiv.

Lloyd's Stainless Steel Soldering Flux

CRES Type 18-8 wire brush

Tempil Stick (400^{o}F)

REPAIR OPERATION SEQUENCE

1. Cleaning & Surface preparation of repair area.

Using clean CRES 18-8 wire brush, buff repair area 1/2 inch around hole edges. Do not wipe with non-metallic. Apply thin coating of flux with brush to repair area. Do not use excess flux.

2. Safety precautions.

Flux contains muriatic acid. Keep off skin, do not breathe fumes. Flush water over any contact area. Call doctor if eyes are contaminated.

3. Application of repair (Technique).

Using Tempil Stick to determine temperature, heat repair area base metal to 400°F. While maintaining temperature, press solder wire end onto repair area and form a thin even coating of solder with a wiping movement. Allow to cool at room temperature.

4. Post-repair cleaning, precautions, checks, etc.

Inspect solder visually for bright, clean appearance. If dull and grain-like in appearance, then re-melt and start over with step one above.

5. Re-repair preparation of unsuccessful repair area.

Heat solder with torch to melting temperature taking care not to overheat excessively. Wipe melting solder away with CRES 18–8 wire brush.

6. Re-repair application technique.

Starting with Step one of the procedure, continue as with original repair.

Repair applied per procedure (4) pcs.

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